POULTRY LITTER MANAGEMENT STRATEGIES TO REDUCE PHOSPHORUS AND NITROGEN RUNOFF FROM PASTURES

By

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FROM PASTURES

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CHAPTER I

INTRODUCTION

Background

Water is an essential resource to all life. Abundant supplies of water are needed for various domestic, agricultural and recreational activities. In the United States, surface and ground waters provide many uses. Recent concern has directed research towards the quality of our nation's waters.

Environmental concerns with non-point source (NPS) pollution has increased due to extensive and localized agricultural operations. In particular, a rapidly expanding poultry industry produced nearly 200 million birds from 600 contract growers in the 13 eastern Oklahoma counties in 1993. Total poultry litter produced is estimated to be approximately 36,000 tons annually; roughly containing 1400 tons total nitrogen (N), 790 tons phosphorus (P), 700 tons potassium (K), plus other plant and animal nutrients, and non-nutrient elements in lesser amounts (Smith et al., 1993).

Recent increasing in poultry production has created a greater awareness of the importance of proper management, utilization, and/or disposal of the poultry litter. Poultry litter includes the manure and bedding (straw, wood chips, rice hulls, etc.) and is a relatively dry material as compared to manure or manure slurry. Land application of poultry litter is considered an acceptable method of utilization. However, surface runoff from land where poultry litter has been applied may contain high levels of nutrients. These elevated nutrient levels may cause degradation of the receiving water.

Pastures with diverse forages and plants with varying growth habits more readily utilize the nutrients present in litter. A forage/grazing system utilizing combinations of warm-season grasses and legumes, and cool-season grasses and legumes customarily have component forage capable of utilizing nutrients from litter.

The movement of phosphorus (P) in runoff can accelerate the eutrophication of surface water. Agricultural soils and management practices that are vulnerable to P loss must be identified before economically viable management systems that minimize P movement can be developed (Sharpley et al. 1995a).

Objectives

There is evidence that nutrient runoff from agricultural areas receiving poultry litter as fertilizer pose a threat to surface water quality. However, the effect of alternative nutrient management scenarios is not well known. The goal of this research is to evaluate management practices that reduce P and N nutrient loading in runoff.

The objective of this study is to determine the difference in nutrient accumulations in soil, and nutrient concentrations and/or loading in surface runoff when litter application is applied on P-basis versus N-basis in an intensively managed grazing system. In summery it seeks to answer the question: Can poultry litter be used in intensively managed pasture grazing systems to optimize forage production without accumulating P in the soil or increasing the concentration of Nitrogen (N) and P in surface runoff?

CHAPTER II

LITERATURE REVIEW

This chapter reviews the literature of poultry litter application and general background on phosphorus buildup in soils and runoff. It reviews soil testing, alternative management strategies, and discusses nutrient loading from agricultural runoff.

In Eastern Oklahoma poultry litter is typically applied as a fertilizer on pastures and forage crops for grazing and/or haying. Inclement weather may prevent timely spreading, forcing producers to stockpile the litter. Few producers, however, have sheds available for storage. Primary concerns with land application of poultry litter include surface and ground water contamination with nutrients and microbes (Gerkin, 1977).

It is a common practice to apply animal waste as a fertilizer based on crop N requirements (Wallingford et al. 1975). The long standing recommendation for rate of poultry litter application to pasture is based on forage N requirement when soil test phosphorus levels are below recommended threshold values (NRCS 1999). Robbins et al. (2000) points out that excessive P runoff into the receiving fresh water ecosytems are possible consequences of this type of management. Edwards and Daniel (1993) reported that in surface applied litter 2.2% to 7.3% of total P in litter was lost in runoff during intensive rainfalls with more than 80% in the soluble reactive phosphorus (SRP) form. Soluble reactive P is immediately available for aquatic biota.

Nutrient loading, especially N and P, to rivers and streams often limits the aesthetic value of the affected bodies of water (Beaulac and Reckhow, 1982). Nutrient enrichment in streams can lead to significant disturbance of the stream ecosystem (Cairns et al., 1992; Novak et al., 2000). Non-point source pollution refers to nutrient sources, such as agricultural runoff, and is responsible for up to 65% of stream designated use impairment (EPA, 1992 and EPA, 1997). In permanent pasture systems many factors affect runoff water quality including forage type, growth, cover, fertilizer applications and rainfall events (McLeod and Hegg, 1984; Nash et al. 2000; Sharpley et al., 1992).

Agricultural producers have attempted to optimize the economic return from nutrient management practices used to produce a crop. The main emphasis is on the expected crop response to added nutrients. In practice, poultry litter has not always been applied to optimize plant nutrient use. Under contemporary circumstances, application of poultry litter may be in excess of plant needs. Also, nutrients may not be available for crop growth at the optimum time, so that they are often released into the air or water. These nutrient losses have prompted concerns about the impact of current nutrient management on environmental quality.

To develop environmentally sound management systems, an understanding of nutrient loss in agricultural systems is essential (Robbins et al., 2000). Nitrogen and phosphorus are the main nutrients of concern. Input from nitrogen and phosphorus in runoff can accelerate eutrophication and impair water quality.

Wilkerson and Stuedemann (1992) recommended that a more precise determination on the fate of N in grazed ecosystems is needed. An environmentally sensitive nutrient management system for grazing and haying would reduce surface nutrient loading and provide an economic incentive to producers by reducing the need to purchase additional nutrients.

Poultry litter has an average N:P ratio of 2:1, and major grain and hay crops use a N:P ratio of approximately 8:1 (Daniel et al., 1993). Therefore, excess phosphorus is supplied when manure is used to meet all N requirements for crop production. When it is applied on a P basis, there may be shortage of N. Continual use of poultry litter on the N basis typically results in very high accumulation of P in soils. Because of concern for P in runoff to sensitive water resources, many waste utilization plans now are based on P.

When animal manure provides nutrients to meet the crop requirements on an N-based application excess phosphorus is applied (Pote et al. 1996). When fertilizers are applied at a high rate, leaching (Chen, et al., 1996) and surface runoff (Edwards et al., 1994) excessive loss of nutrients can occur. As P fertilizer is applied to the soil, it becomes sorbed onto soil particles. The sorption of P is a dynamic process that is limited by soil characteristics such as pH, soluble iron, and other minerals. Phosphorus poorly retained by the soil is potentially more mobile (Chapman et al., 1997).

Phosphorus build-up in soils is a problem with animal manure, particularly in poultry litter. With the rapid growth of the poultry industry, information is needed to determine the impact of land application of poultry litter on the soil and surface waters (Sharpley et al., 1993 and Sharpley, 1995b). Poultry litter application methods need to be agronomically and environmentally sound (Robinison and Sharpley, 1996). To determine the impact phosphorus has on water quality, testing methods using sensitive P tests could provide information about the fate of P in the system (Edwards et al., 1993).

Bioavailable phosphorus (BAP) transported in agricultural runoff can accelerate surface water eutrophication (Sharpley, 1993 and Sharpley et al., 1995a). Bioavailable phosphorus is a measure of the species of P that have a direct impact on aquatic ecosystems; it represents phosphorus available for algae uptake.

Eutrophication is the process of aging of lakes whereby algae and aquatic plants become abundant and waters become deficient in oxygen. Varying amounts of BAP in soils produce changes in the concentration of P found in runoff. Sharpley (1993) suggested using iron oxide-impregnated paper strips as a P sink for BAP in runoff. This method may have the potential for use as an environmental soil P test to indicate soils likely to enrich runoff with sufficient P to accelerate eutrophication. Sharpley (1993) concluded the use of Fe-oxide strips might facilitate estimates of the potential bioavailability of P transported in agricultural runoff. The test may improve assessments that are needed to minimize runoff impact on water bodies.

The management of phosphorus fertilizers and manure requires constant attention to minimize eutrophication in sensitive waters because P-enriched soil increases the chance of transport in runoff. Currently, several states have implemented plans to minimize the amount of P applied in an effort to protect water quality. However, current data for these plans are insufficient (Sharpley, 1995b).

Sharply (1993) investigated the relationship between extractable soil phosphorus P and runoff P concentrations. The study suggests that specific characteristics of the soil be considered in fertility management. The effects of soil type must be integrated with soil test P to develop better estimates for P loss in runoff (Sharpley, 1995b). Sharpley (1995b) suggests that a comprehensive approach that integrates soil P levels with variability of runoff volume and erosion, resulting from climatic, topographic, and agronomic factors is needed for reliable, yet flexible P management recommendations.

Daniel et al. (1993) studied the effect of extractable surface soil phosphorus on runoff water quality. The study focused on P additions to surface water from agricultural nonpoint sources. Numerous sources of P runoff exist: indigenous soil and plant material, land-applied manure, sludge, and commercial fertilizer. Long-term use of these products can lead to high levels of P in the soil. Daniel et al. (1993) proposed methods to identify these increased levels to evaluate potential P loss in runoff. For decades in many parts of the US phosphorus application from animal manure has exceeded rates for crop removal, resulting in widespread build-up of P (Daniel et al., 1993). Both particulate and dissolved forms of P may be transported in agriculture runoff. Particulate P forms usually found in eroded sediments and dissolved P forms found in the solution phase of runoff need to be controlled. Minimizing erosion will control the amount of particulate P, but dissolved P forms are harder to control and test. Daniel et al. (1993) suggest there is a need for a reliable model to predict dissolved P in the runoff. The method should include a provision for the high amount of variability in soil properties.

Currently, standardized tests are used to determine the amount of extractable phosphorus found in the soil. The tests are based upon the nutrient availability for crop uptake. Hooda et al. (2000) suggests the test is not sensitive enough to predict the release of phosphorus to surface runoff already present in the soil system. Most states test for plant availability of P with Bray I and Mehlich III (Gartley and Sims, 1994). Soil test P levels extracted by Bray I and Mehlich III solutions can identify high P levels in the soil above which litter should not be applied. Due to a lack of field data relating Mehlich III to runoff P these critical levels have been based more on assumption than on fact (Sharpley, 1995a).

Pote et al. (1996) developed a relationship between extractable soil phosphorus and phosphorus losses in runoff. They related the variability of runoff and soil test P (STP) to dissolved reactive P (DRP) and bioavailable P (BAP). Previous research indicates that P content in the soil surface directly influences the amount of DRP in runoff. STP and DRP are related. Excess STP can increase DRP levels in runoff. With current soil testing methods, soil fertility testing based on a crop calibration is more readily available than other methods. Pote et al. (1993) hypothesized that the correlation of STP, DRP and BAP in runoff varies with testing methods.

Abrams and Jarrel (1995), in a study in the Tualatin River Basin (TRB) of Northwest Oregon, hypothesized that the major source of P in the basin is the high native soil P concentrations and thus may be significant contributor of P in the watershed. The study further indicated that water percolating through soil with high P content could increase ground water P levels. The enriched ground water concentrations could increase the level of P found in surface water. They concluded that native soil P should not be overlooked during efforts to identify and control nonpoint pollution sources.

Relationships between soil testing and soil history need to be developed. It has been determined that excess fertilizer use and P build-up lead to eutrophication. The first step in preventing these problems is to promote soil testing, quantify nutrient loading, and manage application rates to prevent problems in these areas. Excess application of animal manure can increase STP, and lead to nutrient loading in surface runoff.

Can an environmentally sound grazing management system minimize and protect water quality by minimizing phosphorus loading in runoff and reducing the potential build up of P in soils. In order to create such protocols soil test phosphorus and runoff phosphorus need to be correlated.

CHAPTER III

MATERIALS AND METHODS

This chapter presents material and methods used to collect water, forage, soil samples and conduct the statistical analysis of research data.

Location and Plot Layout

The project was located in LeFlore County at Briggs Ranch in the Poteau River watershed below Lake Wister (Figure 1). Lake Wister is cited in the Oklahoma Section 319 Assessment Report as having impaired recreational and drinking water uses. The Poteau River is also included on the Oklahoma 305(b) list (ODEQ 1998). Much of the watershed contains intensive poultry production. The purpose of the research project was to evaluate best management practices to protect water quality under intensive poultry litter-based forage production and grazing systems.

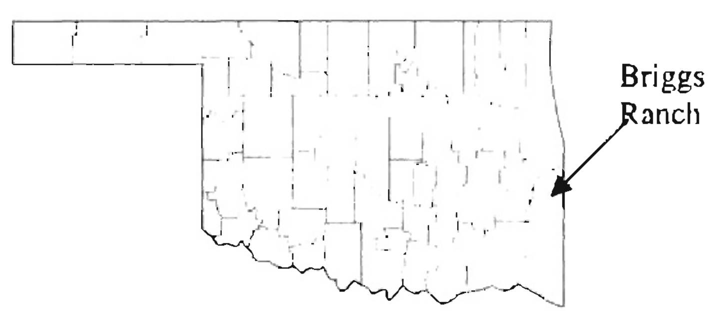

Figure 1. Location of Briggs Ranch project area.

One field from the Briggs Ranch (approximately 51 hectares) was divided into four paddocks with permanent fencing. Treatments were labeled "N-based", "P- based", "control", and "negative control". A summary of treatments is found in Table 1. N-Based, P-Based and control paddocks were approximately 16 hectares each. The negative control treatment (no cattle, no fertilizer) was 3 hectares. Each paddock was maintained with a nutrient management plan and grazing protocol to achieve high, but sustainable production based on Oklahoma State University Cooperative Extension Fact Sheet 2584 Forage-Budgeting Guidelines.

Table 1. Summary of treatments.

	N-Based Treatment	P-Based Treatment	Control	Negative Control
Litter- P_2O_5 kg/ha (lb/ac)	175 (157)*	37 (33)*	None	None
Litter- N kg/ha (lb/ac)	230 (205)*	46 (41)*	None	None
Commercial Fertilizers NH_4NO_3-N* kg/ha (lb/ac)	None	174 (156)	None	None
Forage Yield Goal t/ha (ton/acre)	9 (4)	9 (4)	N/A	N/A
Winter Annuals Planted	Yes	Yes	No	No
Stocking Rate (cow/acre)	45	45	15	0
Soil Sampled Bi-annually	Yes	Yes	Yes	Yes
Forage Samples	35-day intervals	35-day intervals	None	None

*Average of 3 application values shown in Table 3.

The USDA Soil Survey of LeFlore County, Oklahoma (1983) shows the soils in the study area to be Sallisaw loam, Stigler silt loam, and predominately Pirum Clebit Complex. The characteristics of the Pirum series are very similar to what was observed in the field. The Pirum series consists of a moderately deep, well-drained, moderately permeable soil. It is a loamy material derived from weathered sandstone. The slope of this soil ranged from 2 to 60 percent. Maximum slope in the study site is above 8 percent. The surface soil ranged up to 30 percent fragmented sandstone ranging from gravel to stone. The north and south field showed to have a small amount of gravel on the soil surface, whereas the middle fields had very large stones throughout the top meter (3 ft.) of the soil surface.

Permanent rainfall simulator sites were installed in each paddock, for use with portable rainfall simulator to evaluate runoff quality and quantity from each paddock periodically. The rainfall simulator was built by Oklahoma State University, based on the Nebraska rotating boom design (Figure 2) (Huhnke et al., 1992; Storm et al., 1992).

Figure 2. Oklahoma State University rainfall simulator.

The use of the rainfall simulator allowed sampling of runoff without the problems of maintaining stream gages and water quality samplers. The field design and layout are shown in Figure 3. Each paddock received different nitrogen, phosphorus concentrations from applied poultry litter, and commercial fertilizer. Table 2 provides the sequence of events that took place during this study.

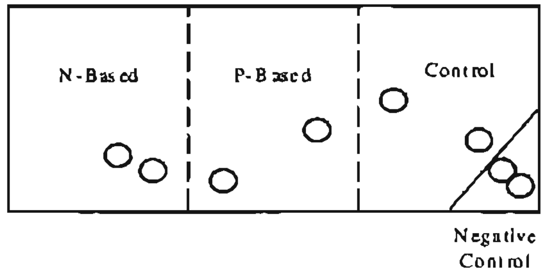

Figure 3. Field design and layout, circles show locations of rainfall simulator sites.

Table 2. Experimental timetable.

May 9, 1997	1st Litter Application
July-August 1997	Plot Construction
April 29, 1998	Rainfall Event I
May 2, 1998	2nd Litter Application
May 21,1998	Rainfall Event II
October 26, 1998	Rainfall Event III
May 17, 1999	Rainfall Event IV
May 19, 1999	3rdLitter Application
June 24, 1999	Rainfall Event V
October 25,1999	Rainfall Event VI

Runoff water samples were analyzed for nitrate-N (NO_3-N), ammonium-N (NH_4-N), total Kjeldahl nitrogen (TKN), soluble reactive phosphorus (SRP), and total phosphorus (TP). The Soil, Water and Forage Analytical Laboratory (SWFAL) (Zhang and Kress, 1997) analyzed soil samples for nitrate-N, organic matter, and Mehlich III P. Soil sampling was conducted twice a year, two weeks prior to litter/fertilizer application. In addition, soil from the rainfall simulator sites was sampled immediately following each rainfall application. Excess forage was harvested as hay, weighed, and analyzed for total N, P, and forage quality. The rate of forage production was measured directly by excluding cattle from selected areas, on exclosures, in each paddock.

Cattle were assigned to graze on all paddocks throughout the course of the demonstration except the negative control. Stocking rates were determined using forage-budgeting guidelines from Oklahoma State University Cooperative Extension OSU Fact Sheet 2584. In determining stocking rate, dry matter (DM) requirements were estimated from annual forage DM production. Nitrogen and phosphorus based treatments had the same stocking rates throughout the growing season, generally about 45 cows per paddock. The control treatment received no fertilizers. Because its DM production was lower, stocking rates were decreased to about 15 cows per paddock.

Nutrient analyses of litter are shown in Table 3. Each litter analysis was sampled and sent to University of Arkansas Analytical laboratory for nutrient analysis. Results were averaged to determine application rates. Each paddock received an amount of litter based on recommendation from fact sheet 2225 OSU Soil Test Interpretations (Table 4). The P-based application received an additional application of commercial fertilizer to meet crop N requirements, based on a yield goal of 9 t/ha. Application was based on total N with no adjustment for availability.

Table 3. Nutrient analyses of poultry litter "as is" basis.

	Litter Analysis		
	N	P_2O_5	K_2O
	----------lb/ton--------		
May 10, 1997	59	34.1	44.7
May 2, 1998	59.7	44.3	48.8
May 19, 1999	49.6	48.4	43.4

Table 4. Litter and commercial fertilizer application Rate

	Manure and Commercial Fertilizer Applied				
	-------N- Based-------		----------------P-Based------------		
	N	P_2O_5	N	C-N*	P_2O_5
	------------------------kg/ha (lb/acre)-------------------				
May 10, 1997	229(204)	132(118)	63(57)	164(147)	37(33)
May 2, 1998	230(205)	170(152)	33(29)	179(159)	44(39)
May 19, 1999	230(205)	224(200)	43(38)	180(160)	30(27)

* Commercial fertilizer ammonium nitrate applied

Site and Plot Preparation

At each prospective plot location, a 16-meter x 16-meter (54-ft x 54-ft) area was first surveyed using a 0.91-meter (3-ft) grid to define the general topography. Next suitable locations for the eight rainfall simulator setups were selected and plot corners were located. Plots were installed July through August 1997.

Permanent simulator sites were constructed by installing low earthen berms 15 cm (6-in.) high by 37 cm (24 in.) wide at the edge of the central alley and along the lower edge of the wetted circle. Berms were stabilized and protected by sod. Berms were wide and low enough to remain in place indefinitely without interfering with cattle or machinery (Figure 4).

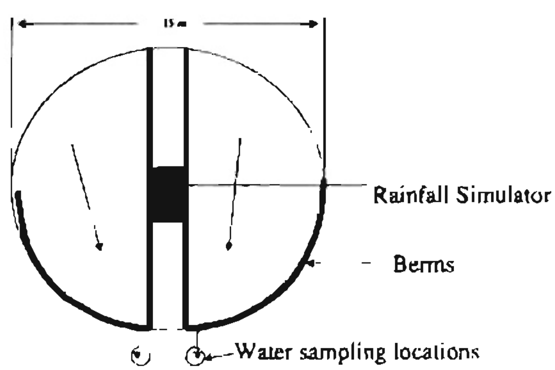

Figure 4. Rainfall simulator plot layout shows alleyways, berms, and sample collection points.

A mild steel funnel was used as an end plate funnel at the lowest corner of each semi-circular plot (Appendix 1). The funnel diverted all runoff water through a 7.6 cm (3 in.) PVC pipe into a collection pit 76 cm (30-in.) diameter by nominally 76-cm (30 in.) deep. Flow rate was measured at the outlet of the PVC pipe and samples collected (Figure 5). The end plate funnel was sealed to the soil surface with melted paraffin wax to insure runoff did not flow underneath. An expanded metal frame covered and protected the collection funnel from cattle and other large contaminants between rainfall simulation events.

Figure 5. Rainfall simulator collection pit with flow measurements and sample collection.

A trencher/back hoe dug the collection pits and installed drainage pipes to empty the collection pits through four-inch PVC pipe. Figure 6 provides a drawing of the collection pit as it collects water and drains.

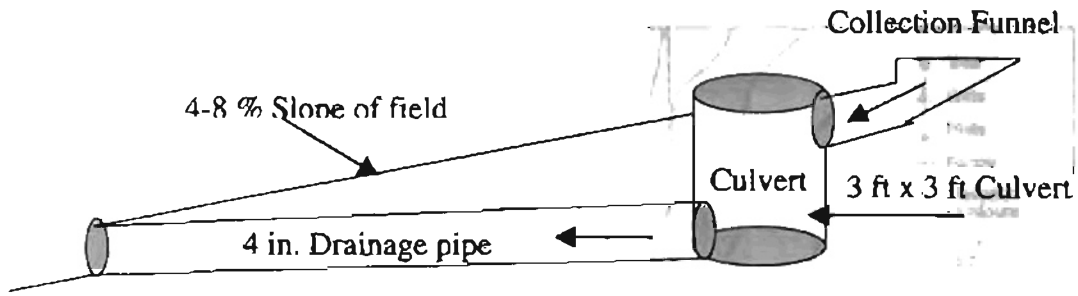

Figure 6. Collection funnel and pit discharge for runoff collection.

Water Supply

Each rainfall simulation setup requires approximately 13,000 liters (3,500 gal) of water. A ¼-acre pond on Briggs Ranch was treated with 2000 lb. alum the afternoon prior to its use as water supply for the simulator to precipitate the P and clay particles from the water. A gas powered water pump was used to apply alum as a slurry. Two gasoline-engine pumps, transferred water from the pond through a two-inch fire hose supplying water to the rainfall simulator. Distances from pond to simulator sites ranged from 91 meters (300 ft) to 426 meters (1400 ft). Elevation changes from the pond to the simulator sites ranged from 4.6 meters (15 ft) to 11 meters (35 ft) above the pond. A 5-hp gasoline pump was placed at the edge of the pond to pump the water 3-9 meters (10–30 ft) up gradient. A second 7-hp pump provided a masthead pressure of 30 psi and maintained flow regulation at the rainfall simulator.

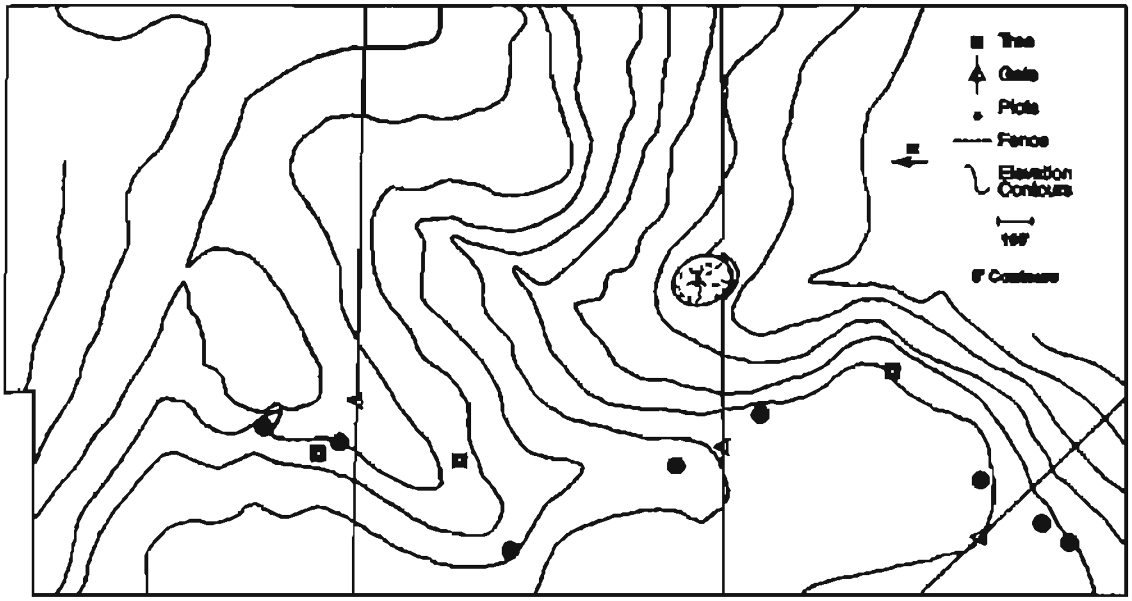

Figure 7. Topographic map shows the distance and hydraulic head.

Rainfall Simulator

Each rainfall simulator setup provided controlled precipitation for two plots simultaneously, A and B. The rainfall simulator was capable of wetting a 15-m (50-ft) diameter area (Huhnke et al. 1993). The simulator was leveled with its center at 2.7 m (9 ft) above the ground. The nozzles spray continuously, while the booms rotate. Closing selected nozzles, rainfall intensity may be set at two nominal rates, 12 and 6 cm/h (5.0 and 2.5 in./h). The boom rotates at approximately four revolutions per minute. A central alley, 3 m (10 ft) wide, between plots, allows room for simulator placement, between semi-circular plot pairs. The rainfall simulator was operated at an intensity of 6 cm/h (2.5 in./hr). Rainfall simulator setup required a complete flush of all lines and nozzles prior to each scheduled rainfall event. If problems appeared, repairs were made immediately.

Soil and Forage Sampling

Two soil probes were used to collect soil samples in the field. The first soil probe had an adjustable sleeve set at 5 cm (2 in.). This allowed the sampler to collect the first 5-cm (2 in.) of the soil sample. The second probe was marked at a depth of 15 cm (6-in.), and used in the same hole. SWFAL recommends a 15-cm (6-in.) depth of sample for agronomic recommendations. A clean plastic bucket was used to mix soil cores before putting soil in to labeled sample bags. Each sample submitted for analyses was a composite sample of 15 cores taken randomly on each plot. The four paddocks were sampled bi-annually, once in the early April and once in October before litter was applied. Two sets of soil samples were taken from each plot after every simulated rainfall at 0-5 cm (0-2 in.) and 5-15 cm (2-6 in.). Soils sample bags were labeled by location, depth, and date of sampling.

Forage samples were collected throughout the growing season on 35-day intervals. Three randomly placed grazing exclosures were maintained in each treatment except the negative control. Samples were clipped at approximately 2-cm (¾ in.) height to mimic that of forage removal by haying. Forage samples were collected from a randomly placed 9 cm x 18 cm (1ft x 2 ft) PVC grid. Subsequent to collection of the samples from a grazing exclosure, all remaining standing forage was cut with a weed eater, raked and removed from the exclosure. Collected samples were placed in paper bags labeled as to date and location of collections. Samples were air-dried, weighed and shipped to the laboratory in their sample bags. Samples were analyzed for moisture, crude protein, ADF, TDN, net energy maintenance, lactation and growth, calcium, P, K, sulfur, magnesium, sodium iron, manganese, copper, and zinc.

Runoff Sampling and Analysis

Seven 500-ml runoff samples and one rainwater sample were collected from each plot during rainfall simulator-runoff events. After each rainfall simulator-runoff event, samples were taken to a field laboratory where they were split into three sub-samples, two of which were filtered (0.45 μm pore diameter). One filtered 60-ml subsample was preserved for NO_3-N and NH_4-N with 0.2 ml of 4M sulfuric acid solution to reduce pH to 2. The other filtered 60-ml sample was used for Soluble Reactive Phosphorus analysis without preservation. All subsamples were cooled with ice immediately after filtration. The remaining 320 ml of sample was frozen for analysis of Total P and total Kjeldahl nitrogen (TKN). All the filtered samples were taken to OSU SWFAL for further analysis within 24 hours.

Quality Assurance and Quality Control

During scheduled rainfall events a coordinating supervisor (the pit-bull) was in charge of monitoring, and recording all sampling times. The pit-bull would notify the water pit crew when to take samples. All water samples were collected in polyethylene containers, labeled with indelible ink according to rainfall event, simulator setup, and sample sequence number.

During each rainfall simulation event, seven runoff samples were collected from each plot and one rainwater sample. Simulator supervisor (water boy) collected rainwater samples (field blank) by placing a pre-labeled polyethylene container under the rotating boom. A spike, split and duplicate were also submitted with water samples from each rainfall simulation circle. The spikes and splits were created during field laboratory filtration by splitting a predetermined subsample into two 60 ml vials, spikes and splits were handled identically to runoff samples. Quality control checks were assigned to runoff-collected subsample #4. The spikes and splits were assigned to samples 1A, 3A, 5A, 7A, 2B, 4B, 6B, and 8B. While the numbers in front of the letter signify from which simulation site the sample originated. Spike samples originated from 1A4, 3A4, 5A4, and 7A4, splits were assigned to samples 2B4, 4B4, 6B4, and 8B4. The field laboratory finished separating all subsamples by placing them in the appropriate cooler for delivery to SWFAL. The results of the quality assurance and quality control are found in appendix 2.

SWFAL analyzed both preserved (Nitrate and Ammonia) and unperserved (Ortho-P) samples within 24-hours. All samples received the same quality control checks throughout the project. The analytical methods used by SWFAL are shown in Table 5.

Table 5. Nutrient analysis and chemical method used by SWFAL.

Analyte	Method*
Ammonia (Phenolate) in potable and surface waters.	QuickChem Method 10-107-06-1-B
Nitrate/Nitrite, Nitrite in surface water, wastewater.	QuickChem Method 10-107-04-1-A
Orthophosphate in waters	QuickChem Method 10-115-01-1-A

*Lachat Instruments, 6645 West Mill Road, Milwaukee, WI 53218

Statistical Analyses

The experimental design was a 4 x 6 factorial arrangement of treatment in a completely randomized design. The factors of interest were date (6 levels) and treatment (4 levels). Treatment levels were litter applications based on crop-N requirements with grazing (N-based), litter and commercial fertilizer application based on crop-P requirements with grazing (P-based), no fertilizer with grazing (control), and one without fertilizer or grazing (negative control). Treatment effects were examined on the following parameters:

Runoff Volume

Soil Test Nitrate-N (NO_3-N)

Soil Test Ammonium (NH_3-N)

Soil Test Phosphorus

Runoff Nitrate-N

Runoff Soluble Reactive Phosphorus

All statistical analyses were performed at an alpha level of 0.05 (α=0.05). The soil samples from 0-5 cm (0-2 in.) and 5-15 cm (2-6 in.) were analyzed separately. PROC MIX from SAS software performed the analyses of variance (ANOVA) (SAS Institution Inc,. 1999).

Simple effects (treatment and date) were evaluated first for each variable holding one factor constant with the slice option from the LSMEAN procedure statement. The DIFF option from the LSMEANS procedure compared mean by a least significant difference procedure when overall simple effects of a factor were significant.

Total Load and Flow Weighted Mean Concentration

The flow-weighted mean concentration was calculated for each plot, A and B. All information to complete the calculation was obtained from rainfall runoff and nutrient concentrations. Flow-weighted mean concentrations were calculated as the ratio of total load to total flow value from the following equations. Equation (1) was used to compute load, and equation (2) was used to compute flow. Equation (3) was used to compute the flow weighted mean concentration for each plot. In each equation, $_{i-1}$ is where runoff begins.

$$L = \sum_{i=1}^{n} \Delta t_i \frac{(Q_{i-1} + Q_i)}{2} * C_i \qquad (1)$$

$$F = \sum_{i=1}^{n} \Delta t_i \frac{(Q_{i-1} + Q_i)}{2} \qquad (2)$$

$$FWM = \frac{L}{F} \qquad (3)$$

Q= bucket volume (l)/ fill time (s)
C= nutrient concentration (mg l^{-1})
t= time after rainfall
L= flow-weighted average (mg)
F= total flow (l)
FWM= flow weighted mean concentration
n= number of intervals
$\Delta t_i = t_{i.} - t_{i-1}$

All information to complete the calculation was obtained from the start of runoff to the last runoff sample.

CHAPTER IV

RESULTS

Soil Nitrate-N

Soil nitrate-N concentrations varied throughout the course of the project. Figures 8 and Figure 9 show nitrate-N at soil depths 0-5 cm (0-2 in.) and 5-15 cm (2-6 in.). Soil nitrate concentrations in both N-based and P-based treatments were similar in the top of the soil profile 0-5 cm (0-2 inches) depth. May 2, 1998 and May 19, 1999 litter and commercial fertilizers were applied to the appropriate fields, litter producing higher soil nitrate-N mean concentration on soil sampling dates May 21,1998 and June 26,1999. The control and negative control were similar to one another and always lower than either N-based or P-based treatments. Through the season soil nitrate-N concentrations decreased more rapidly in the P-based treatment than in the N-based treatment, but two years after the poultry litter application the P-based and N-based treatments were similar to the control and negative controls (May 17, 1999).

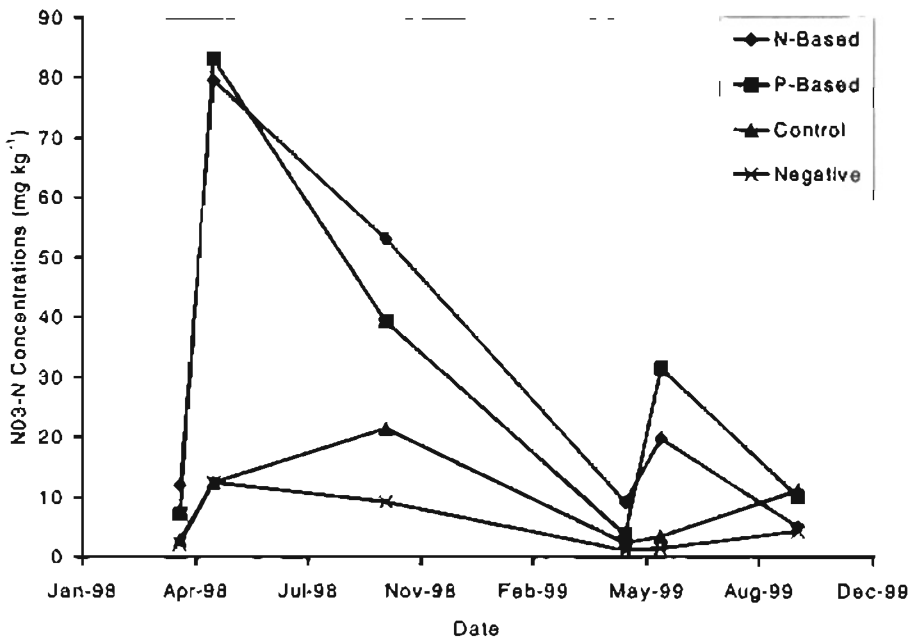

Figure 8. Soil test nitrate-N concentration at 0-5 cm (0-2 in.). Litter application dates: May 9, 1997, May 2, 1998, and May 19, 1999.

Soil nitrate-N concentrations, at depths of 5-15 cm (2-6 in.), followed the same trends as the 0-5-cm (0-2 in.) before and after litter and fertilizer applications. Soil nitrate-N on the P-based treatments were higher than N-based treatments immediately after litter and commercial fertilizer applications as indicated in Figure 9 (May 21, 1998 and June 26, 1999).

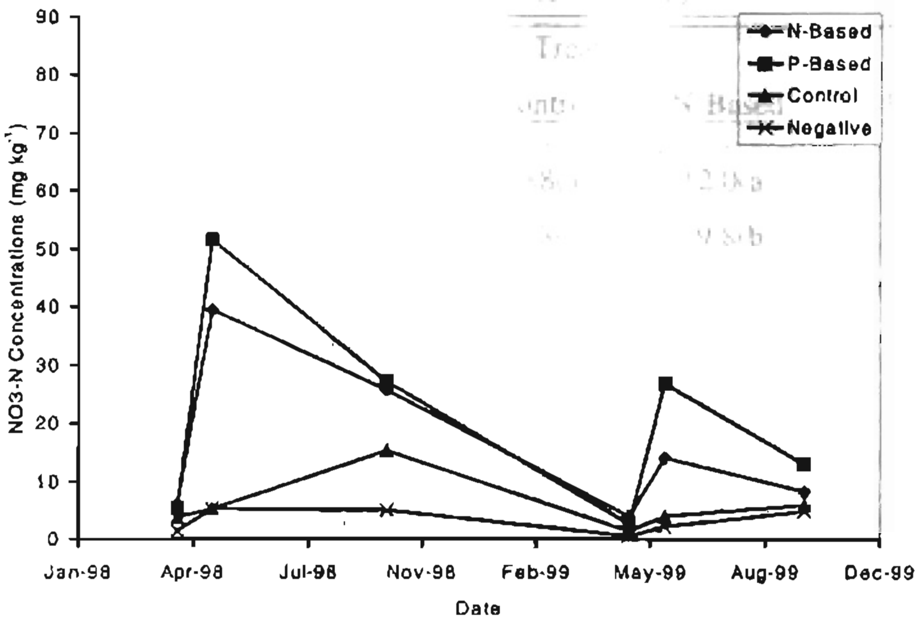

Figure 9. Soil test nitrate-N concentration at 5-15 cm (2-6 in.). Litter application dates: May 9, 1997; May 2, 1998 and May 19, 1999.

Analysis of treatment means of soil NO_3-N by least significant difference by date (Table 6) shows no significant difference between controls and treatments one year after litter and commercial fertilizer application (April 1998 and May 1999). There was a significant difference between treatments and controls immediately after the second litter application (May 21, 1998). In October 26, 1998, NO_3-N was significantly higher in soil test nitrate-N from N-based treatment than either P-based or control treatments. Following the third litter application, N-based and P-based treatments were least significant different, but there were no significant differences between treatments and controls four months later (October 25, 1999).

Table 6. Soil nitrate-N treatment means at 0-5 cm (0-2 in.).

Date	Treatment			
	Negative	Control	N-Based	P-Based
	---------------------------mg kg^{-1}---------------------			
April 29, 1998	2.13(a)	2.88(a)	12.0(a)	7.25(a)
May 21, 1998	12.5(a)	15.8(a)	79.8(b)	83.3(b)
October 26, 1998	9.25(a)	21.5(a)	53.3(c)	39.3(b)
May 17, 1999	1.00(a)	2.38(a)	9.25(a)	3.75(a)
June 26, 1999	1.38(a)	3.50(a)	24.9(b)	31.5(b)
October 25, 1999	4.35(a)	11.6(a)	5.10(a)	10.5(a)

Different letters within a row denote significant difference between treatment groups on that date (α=0.05).

Table 7, provides soil nitrate-N results for 5-15 cm (2-6 in) depth. The analysis of least significant differences for soil NO_3-N by date showed a significant difference between treatments and controls for P-based and N-based application immediately following litter and commercial fertilizer application (May 21, 1998 and June 26, 1999). The P-based treatment was significantly higher than the N-based treatment (May 21, 1998 and June 26, 1999). There was a significant difference between controls and treatments for October 26, 1998, four months after the second litter applications. The difference between control and negative control on October 26, 1998 was probably due to fresh cattle manure near the runoff collector on one of these plots. There was not a significant difference between controls and treatments one year after the second litter application (May 17, 1999).

Table 7. Soil nitrate-N treatment means at 5-15 cm (2-6 in.).

Date	Treatment			
	Negative	Control	N-Based	P-Based
	--------------------------mg kg^{-1}--------------------			
April 29, 1998	1.50(a)	3.88(a)	6.13(a)	5.38(a)
May 21, 1998	5.25(a)	12.5(a)	39.5(b)	51.5(c)
October 26, 1998	5.00(a)	15.3(b)	25.8(c)	27.3(c)
May 17, 1999	0.63(a)	1.50(a)	4.00(a)	2.63(a)
June 26, 1999	2.25(a)	4.00(a)	17.8(b)	26.9(c)
October 25, 1999	4.95(a)	5.98(a)	8.25(a)	13.1(a)

Different letters within a row denote significant difference between treatment groups on that date (α=0.05).

Soil Ammonium

Figures 10 and 11 show NH_4-N from soil depths at 0-5 cm (0-2 in.) and 5-15 cm (2-6 in). Overall, soil NH_4-N concentrations for N-based and P-based treatments at both depths were similar to the controls. There was a slight difference between the controls and both N-based and P-based treatments on October 26, 1998 and on June 26, 1999 in the 0-5 cm (0-2 in.) depth. In the 5-15 cm (2-6 in.) depth soil NH_4-N on the P-based treatments and N-based treatments were lower than the controls immediately after litter and commercial fertilizer applications as indicated in Figure 11 dates, May 21,1998 and June 26, 1999.

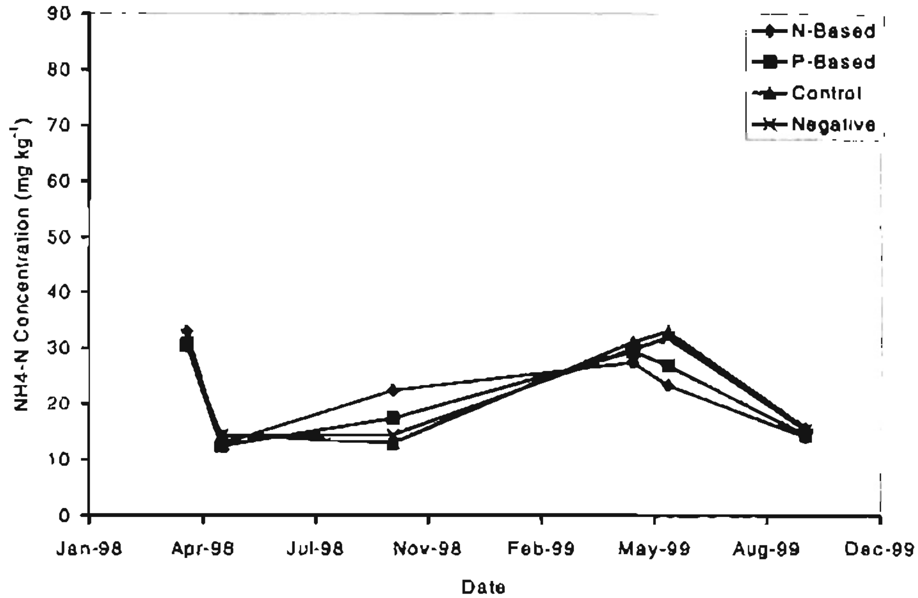

Figure 10. Soil test ammonium-N concentration at 0-5 cm (0-2 in.). Litter application dates: May 9, 1997; May 2, 1998, and May 19,1999.

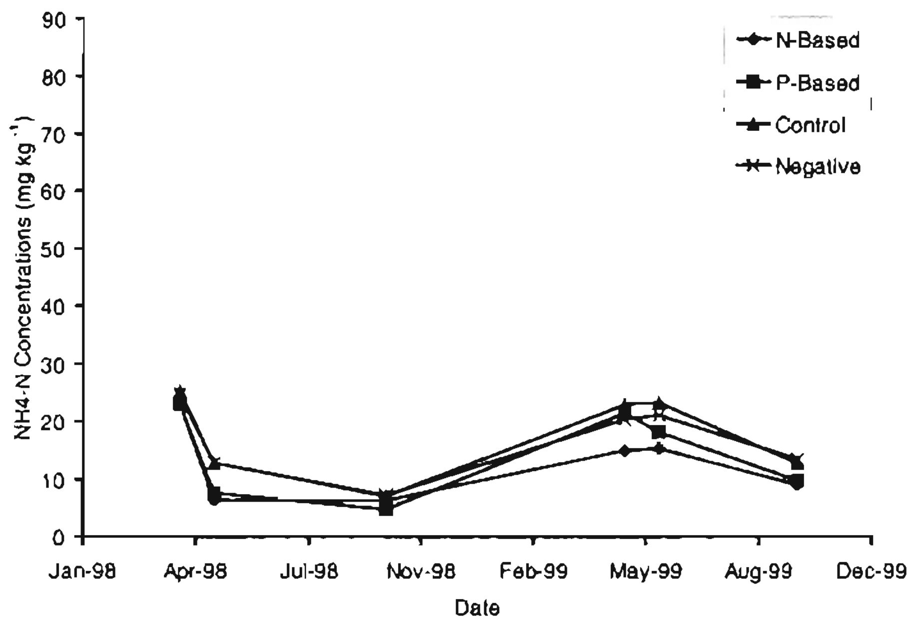

Figure 11. Soil test ammonium-N concentrations at 5-15 cm (2-6 in.). Litter application dates: May 9, 1997, May 2, 1998, and May 19, 1999.

Analysis of treatment means of soil NH_4-N by least significant difference by date (Table 8) shows no significant difference between controls and treatments on April 29, 1998, May 21, 1998, May 17, 1999 and October 25, 1999. However, there was a significant difference between the N-based treatment and control five months after the second litter application (October 26, 1999), with the mean concentration higher in the N-based treatment. There was a significant difference between N-based treatments and controls on the third litter application (June 26, 1999). However, the soil NH_4-N means for the controls were higher than N-based and P-based treatments after litter application (May 17, 1998 and June 26, 1999).

Table 8. Soil ammonium-N treatment means at 0-5 cm (0-2 in.).

Date	Treatment			
	Negative	Control	N-Based	P-Based
	------------------------mg kg^{-1}--------------------			
April 29, 1998	30.8(a)	30.5(a)	33.0(a)	30.8(a)
May 21, 1998	14.3(a)	16.5(a)	12.8(a)	12.5(a)
October 26, 1998	14.5(a)	13.0(a)	22.5(b)	17.5(a,b)
May 17, 1999	29.8(a)	31.2(a)	27.5(a)	29.6(a)
June 26, 1999	32.0(b)	33.0(b)	26.2(a)	26.9(a,b)
October 25, 1999	15.4(a)	13.0(a)	22.5(a)	17.5(a)

Different letters within a row denote significant difference between treatment groups on that date (α=0.05).

Table 9, provides the results for 5-15 cm (2-6 in) depth. The analysis of least significant differences for soil NH_4-N by date showed no significant difference between treatments and controls on April 29, 1998 and October 26, 1998. There was a significant difference between controls and treatments in the remaining dates. The controls mean concentrations were always higher than the N-based and P-based treatments after the second litter application and continuing throughout the project.

Table 9. Soil ammonium-N treatment means at 5-15 cm (2-6 in.).

Date	Treatment			
	Negative	Control	N-Based	P-Based
	------------------------mg kg^{-1}-------------------			
April 29, 1998	24.8(a)	25.3(a)	23.3(a)	23.0(a)
May 21, 1998	12.8(b)	12.0(b)	6.25(a)	7.5(a)
October 26, 1998	7.25(a)	7.00(a)	3.25(a)	4.75(a)
May 17, 1999	20.3(b)	22.9(b)	14.9(a)	21.5(b)
June 26, 1999	21.1(b)	23.3(b)	17.7(a)	18.2(a,b)
October 25, 1999	13.6(b)	12.8(b)	9.00(a)	9.08(a)

Different letters within a row denote significant difference between treatment groups on that date (α=0.05).

Soil Test Phosphorus

Figures 12 and 13 show STP from soil depths at 0-5 cm (0-2 in.) and 5-15 cm (2-6 in.). Concentrations of STP at 0-5 cm depth (0-2 inches) were consistently higher in N-based treatments compared to P-based treatments and control. On May 2, 1998 and May 19, 1999 litter and commercial fertilizers were applied to the appropriate plots. This application of poultry litter produced a higher STP mean concentration at the next sampling on May 21, 1998 and June 26, 1999. The control and negative control were similar to one another, but there was a large difference between the controls and both N-based and P-based treatments after fertilizer was applied. Soil test phosphorus of the P-based treatment was less variable than in the N-based treatment.

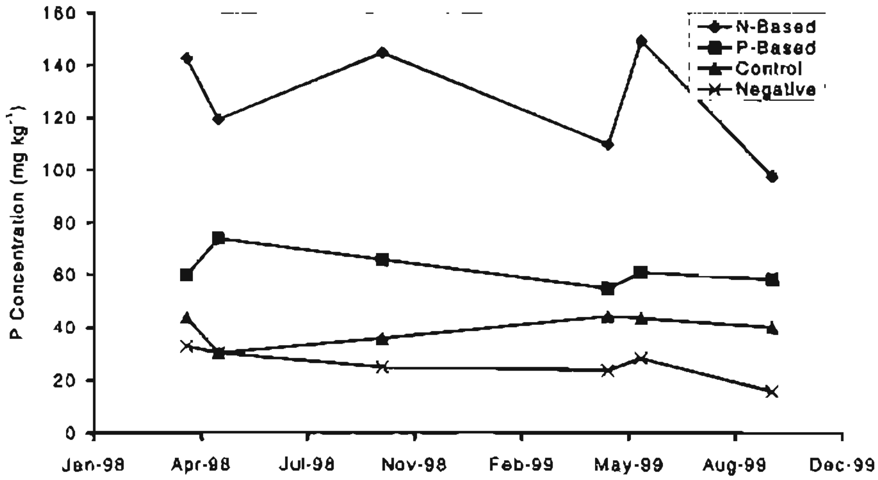

Figure 12. Soil test phosphorus concentration at 0-5 cm (0-2 in.). Litter application dates: May 9, 1997, May 2, 1998, and May 19, 1999.

Soil test phosphorus (STP) concentrations, at depths of 5-15 cm (2-6 in.), followed different trends from the 0-5 cm (0-2 in.) before and after litter and fertilizer applications (Figure 13). Soil test phosphorus on the P-based treatments were always lower than N-based treatments. The P-based treatment STP means were somewhat higher than the controls treatments at 5-15 cm (2-6 in.). The N-based treatment stands out as always, more than twice as high as controls.

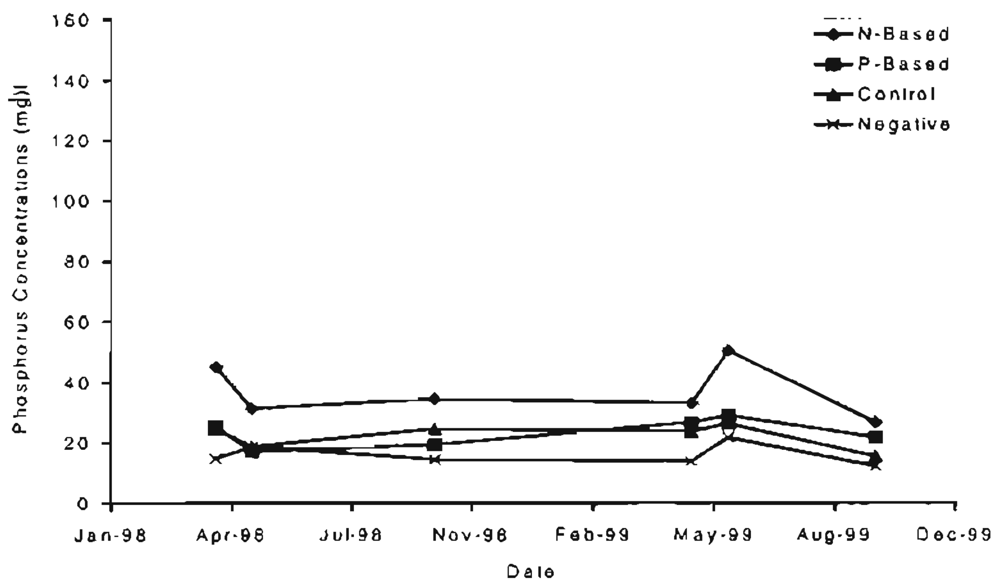

Figure 13. Soil test phosphorus concentrations at 5-15 cm (2-6 in.). Litter application dates: May 9, 1997, May 2, 1998, and May 19,1999.

An analysis of treatment means for STP by least significant difference by date for 0-5 cm (0-2 in) depth is shown in Table 10. All treatments were significantly different from controls. Control and negative control treatment were not significantly different on any date. N-based treatment was significantly higher than the P-based treatment on every date. The P based treatment was significantly different from the control and negative control on all sample dates. There was no apparent trend in STP over the two year period.

Table 10. Soil test phosphorus means at 0-5 cm (0-2 in.).

Date	Treatment			
	Negative	Control	N-Based	P-Based
	mg kg^{-1}			
April 29, 1998	33.0(a)	43.9(a)	142(c)	59.6(b)
May 21, 1998	30.3(a)	38.5(a)	119(c)	73.8(b)
October 26, 1998	25.2(a)	36.0(a)	145(c)	66.0(b)
May 17, 1999	24.0(a)	44.4(a)	143(c)	59.6(b)
June 26, 1999	28.4(a)	43.5(a)	136(c)	60.8(b)
October 25, 1999	15.8(a)	40.1(a)	97.8(c)	58.2(b)

Different letters within a row denote significant difference between treatment groups on that date (α=0.05).

Table 11 provides STP results for 5-15 cm depth (2-6 in). The analysis of treatment mean for STP by least significant differences by date showed no significant difference between controls. N-based treatment was significantly higher than control, negative control and P-based treatment on all dates. N-based and P-based treatments were not significantly different from one another on sample dates May 17, 1999 and October 25, 1999. N-based treatment STP was significantly higher than P-based treatments and controls on June 26, 1999 after the third litter application. The difference did not persist into October 25, 1999.

Table 11. Soil test phosphorus means at 5-15 cm (2-6 in.).

Date	Treatment			
	Negative	Control	N-Based	P-Based
	mg kg^{-1}			
April 29, 1998	14.8(a)	24.8(a)	45.3(b)	25.5(a)
May 21, 1998	18.8(a)	19.6(a)	31.5(b)	17.3(a)
October 26, 1998	14.5(a)	24.6(a)	34.8(b)	19.5(a)
May 17, 1999	13.8(a)	23.8(a)	33.1(b)	26.9(b)
June 26, 1999	21.8(a)	26.4(a)	47.6(b)	29.0(a)
October 25, 1999	12.3(a)	15.5(a)	26.8(b)	21.8(a,b)

Different letters within a row denote significant difference between treatment groups on that date (α=0.05).

Rainfall

Naturally occurring rainfall can affect the flow-weighted mean concentrations of nutrients in runoff over time. There was a very dry period from April 1998 to October 1998. After October 1998 rainfall increased. Appendix 3 shows monthly rainfall totals from three different sites located near the project area. Figure 14 provides an averaged monthly total of rainfall from the three sites. The observations below are discussed based on simulated rainfall from the portable rainfall simulator.

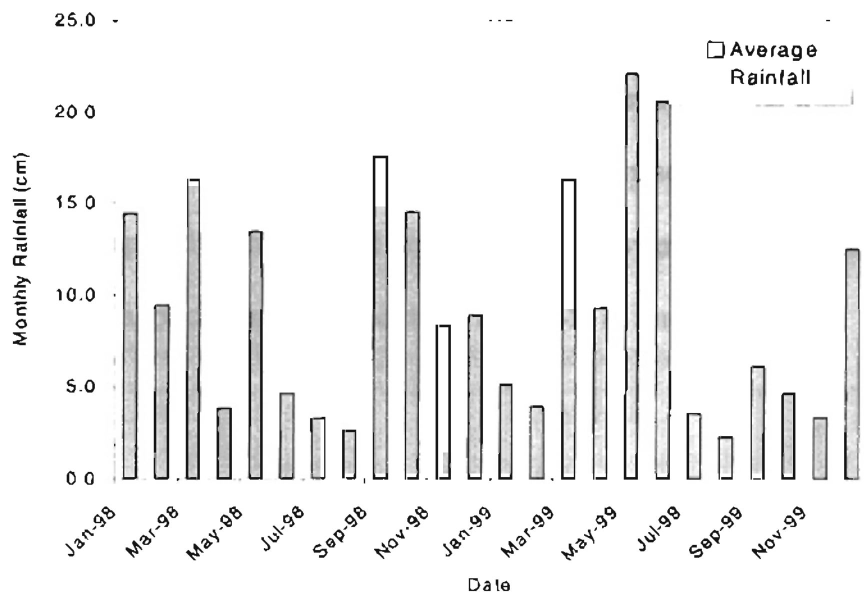

Figure 14. Monthly rainfall totals, average from three nearby stations (Mesonet, Heavener, Poteau).

Water Quality Data

The flow-weighted mean concentrations from simulated rainfall events were used to describe runoff nutrient losses. Figures 15 through 17 show all flow-weighted mean concentrations for all simulation sites. Inconsistencies in one of the runoff plots are discussed later. Because replication was low in this experiment, there was no way to statistically determine if one or another plot was an outlier.

Nitrate

Nitrate-N flow-weighted mean runoff concentrations are shown graphically in Figure 15. One year after the first litter application all treatments were very similar during the April 29, 1998 rainfall event. Immediately after the second litter application, nitrate-N in the P-based treatment runoff was higher than in the N-based treatment (May 21, 1998, and June 26, 1999). From April 98 to October 98 there were long periods without rainfall which consequently left more nitrate-N at the surface causing increased mean runoff concentrations. Five months after the second litter application (October 26, 1998), the N-based treatment was at its highest because of high nitrate in the source water used for the rainfall simulator. On June 26, 1999 both N-based and P-based treatments were lower in concentrations compared to the May 21, 1998 rainfall. However, during both rainfall events the P-based application produced more nitrate-N in runoff.

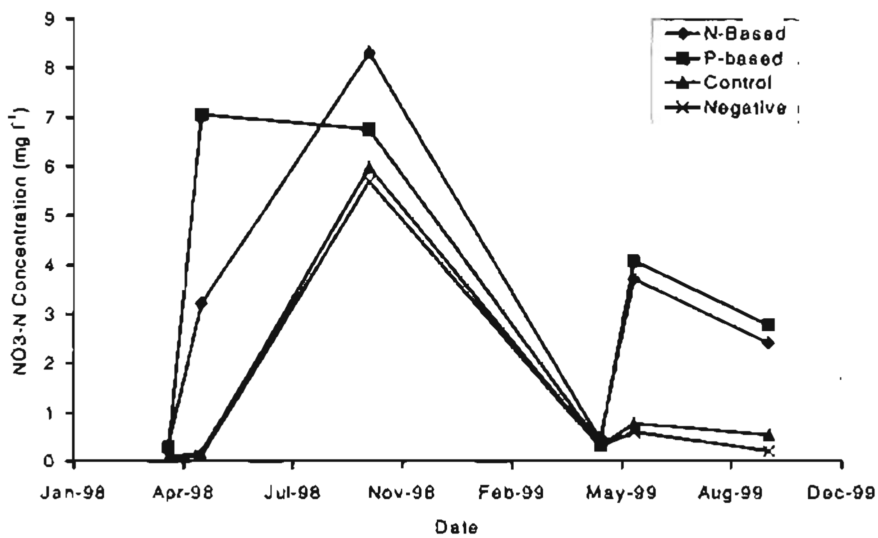

Figure 15. Nitrate-N flow-weighted mean concentrations. Litter application dates: May 9, 1997, May 2, 1998, and May 19,1999.

An analysis of Nitrate-N flow-weighted treatment mean concentrations by least significant difference is shown in Table 12. Mean concentrations of control, negative control, N-based and P-based treatments were not significantly different on April 29, 1998 and May 17, 1999, one year after litter application. Control and negative control treatments were not significantly different from each other on all dates. The P-based treatment was significantly higher than the N-based on May 21,1998, however, this corresponds to poultry litter and commercial fertilizer being applied just weeks before sampling. June 26, 1999 during wet weather N-based and P-based treatments were not significantly different. N-based and P-based treatments were not significantly different (α=0.05) from one another on sample dates October 26, 1998 and October 25, 1999.

Table 12. Runoff nitrate-N flow-weighted mean concentrations.

Date	Treatment			
	Negative	Control	N-Based	P-Based
	---------------------------mg l^{-1}---------------------			
April 29, 1998	0.07(a)	0.09(a)	0.32(a)	0.28(a)
May 21, 1998	0.10(a)	0.16(a)	3.23(b)	7.06(c)
October 26, 1998	5.69(a)	5.97(a)	8.31(b)	6.76(b)
May 17, 1999	0.30(a)	0.30(a)	0.46(a)	0.36(a)
June 26, 1999	0.59(a)	0.77(a)	3.71(b)	4.07(b)
October 25, 1999	0.21(a)	0.53(a)	2.42(b)	2.77(b)

Different letters within a row denote significant difference between treatment groups on that date (α=0.05).

Ammonium

Ammonium (NH_4-N) flow-weighted means concentrations are shown graphical in Figure 16. Initially, April 29, 1998, P-based, control, and negative control treatments were very similar (less than 1 mg l^{-1}) whereas the N-based treatment was about 2 mg l^{-1}. P-based treatments were also higher during the May 21, 1998 and June 26, 1999 rainfall events immediately following litter and commercial fertilizer application.

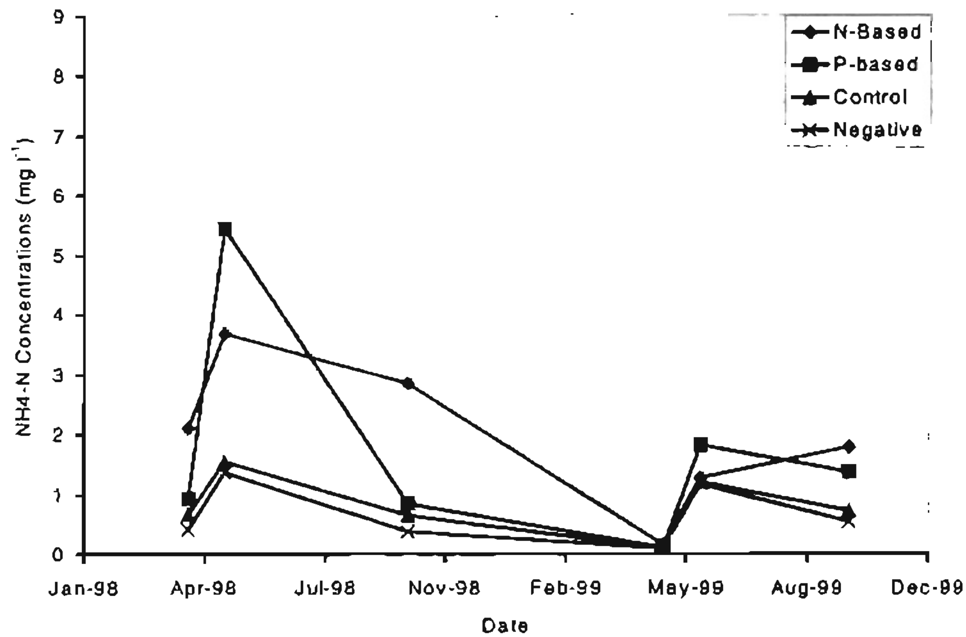

Figure 16. Ammonium-N flow-weighted mean concentration. Litter application dates: May 9, 1997, May 2, 1998, and May 19 1999.

Analysis of ammonium flow-weighted mean concentrations by least significant difference by date showed no significant difference among all treatments on May 17, 1999, June 26, 1999 and October 25, 1999 (Table 13). Control and negative controls were not significantly different from one another on any date. N-based and P-based treatments were significantly different (α=0.05) from one another on sample dates April 29, 1998, October 26, 1998 and May 21, 1998. The P-based treatment mean concentration was higher than the N-based treatment on May 21,1998, during a dry period from April 98 to October 98. The higher rainfall in May 1999 had lower runoff ammonium concentration after litter application. Note the high ammonium-N concentration in the June 26, 1999, was generally lower than the concentration in supply water of the simulator on that date (Appendix 2).

Table 13. Runoff ammonium-N flow-weighted mean concentrations.

Date	Treatment			
	Negative	Control	N-Based	P-Based
	---------------------------mg l^{-1}---------------------			
April 29, 1998	0.42(a)	0.67(a)	2.12(b)	0.94(a)
May 21, 1998	1.37(a)	1.55(a)	3.67(b)	5.44(c)
October 26, 1998	0.38(a)	0.65(a)	2.85(b)	0.84(a)
May 17, 1999	0.08(a)	0.09(a)	0.16(a)	0.10(a)
June 26, 1999	1.17(a)	1.20(a)	1.28(a)	1.83(a)
October 25, 1999	0.54(a)	0.73(a)	1.79(a)	1.37(a)

Different letters within a row denote significant difference between treatment groups on that date (α=0.05).

Soluble Reactive Phosphorus

Soluble reactive phosphorus (SRP) flow-weighted mean concentrations are shown graphically in Figure 17. One year after litter and fertilizer application, April 29 1998, the N-based treatment was significantly higher than P-based, control and negative control treatments. Following the second litter application, and continuing throughout the project N-based and P-based treatments were very similar in runoff mean concentration. The N-based treatment had a higher SRP concentration on all rainfall events. However, the P-based treatment followed the same trend as the N-based treatment but at a lower SRP concentration. The control and negative control treatments were almost identical throughout the course of the project.

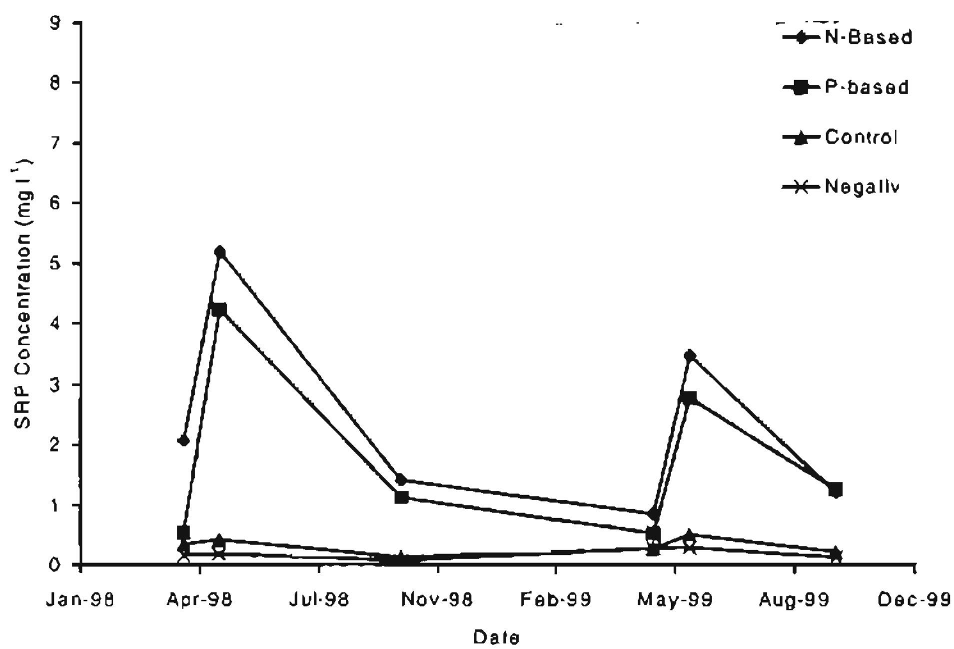

Figure 17. Soluble Reactive Phosphorus flow-weighted mean concentrations. . Litter application dates: May 9, 1997, May 2,1998 and May 19 1999.

Analysis of SRP flow-weighted mean concentrations by least significant difference by date showed on significant difference between the N-based and P-based treatments following litter and commercial fertilizer applications (May 21, 1998 and June 26, 1999) (Table 14). Control and negative control treatments were not significantly different from one another on any date. N-based and P-based treatments were not significantly different from one another on any sampling date except April 29, 1998.

Table 14. Runoff Soluble Reactive Phosphorus flow-weighted mean concentrations.

Date	Treatment			
	Negative	Control	N-Based	P-Based
	------------------------mg l^{-1}-------------------			
April 29, 1998	0.16(a)	0.34(a)	2.07(b)	0.54(a)
May 21, 1998	0.18(a)	0.42(a)	5.20(b)	4.24(b)
October 26, 1998	0.07(a)	0.13(a)	1.40(a)	1.12(a)
May 17, 1999	0.12(a)	0.26(a)	0.85(a)	0.52(a)
June 26, 1999	0.28(a)	0.51(a)	3.48(b)	2.78(b)
October 25, 1999	0.13(a)	0.21(a)	1.20(a)	1.26(a)

Different letters within a row denote significant difference between treatment groups on that date (α=0.05).

CHAPTER V

DISCUSSION

The differences of runoff SRP between N-based and P-based treatments immediately after litter application was not as large as expected considering previous rainfall simulation experiments. Storm et al. (1992) found SRP in runoff from the first rainfall event to be directly proportional to litter application rate. In the present study, litter application rate in the N-based treatment was 4.7 times higher than the P-based treatment (175 hg ha^{-1} vs. 37 kg ha^{-1} as P_2O_5). Table 14 shows that differences between N-based and P-based treatment were small and not significant (α=0.05), suggesting there was a problem in one or more plots. Because replication was low in this experiment, there was no way to statistically determine which plot was an outlier. One possibility is that additional litter might have been dropped on plot three accidentally. I tried removing one plot at a time to determine which had the most effect. Removing plot 3 gave results closest to my expectations. Removing plot 3 also did not change the nitrate or ammonium flow-weighted mean runoff concentrations.

Figure 18 displays flow-weighted mean runoff concentrations for P-based treatment with and without plot 3, compared with the N-based treatment. During the first rainfall event, one year after the first litter application, removing plot 3 had no effect on mean runoff SRP concentrations. After litter application, removing plot 3 reduced mean SRP in runoff by half. A decrease by half is also seen in June 26, 1999 shortly after the third litter application. With plot 3 removed the difference between N-based and P-based runoff SRP was increased about 2 ½ times. This is closer to previous studies, since almost 5 times as much litter was applied to the N-based treatment.

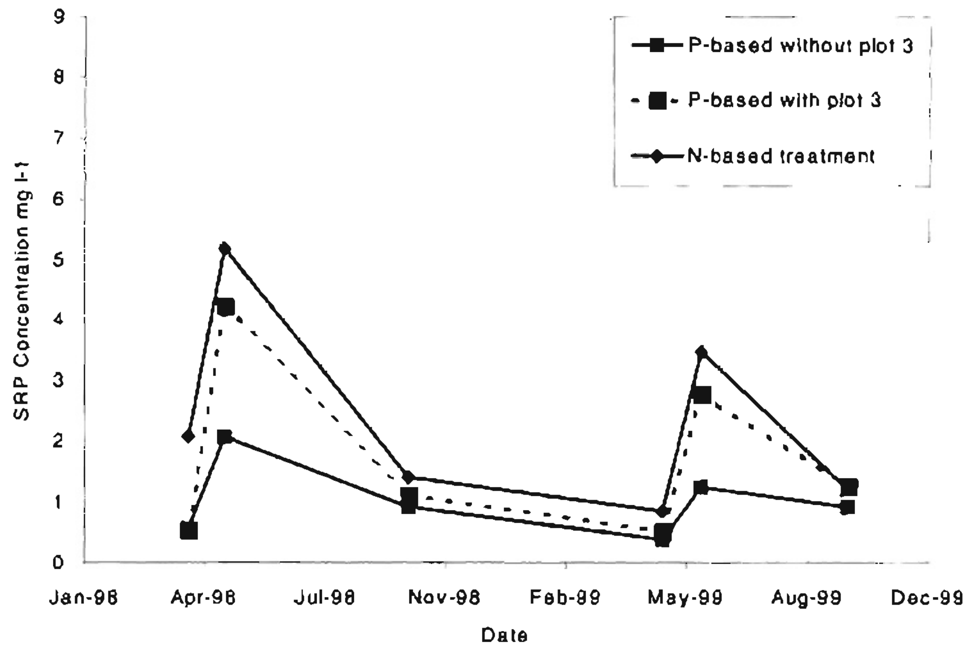

Figure 18. Soluble Reactive Phosphorus flow-weighted mean concentrations showing plot 3's effect on the site. . Litter application dates: May 9, 1997, May 2, 1998 and May 19, 1999.

The analysis of SRP flow-weighted treatment mean concentrations by least significant difference, with plot 3 removed is shown in Table 15. In this case, the P-based treatment was not significantly different from the control and negative control on any date except May 21, 1999, about two weeks after litter was applied. Mean runoff SRP from N-based treatment was significantly higher than the P-based treatment on May 21, 1998 and June 26, 1999 immediately following application.

Table 15. Runoff Soluble Reactive Phosphorus flow-weighted mean concentrations. Plot 3 removed.

Date	Treatment			
	Negative	Control	N-Based	P-Based
	----------mg l^{-1}----------			
April 29, 1998	0.16(a)	0.34(a)	2.07(b)	0.64(a,b)
May 21, 1998	0.18(a)	0.42(a)	5.2(c)	2.07(b)
October 26, 1998	0.07(a)	0.13(a)	1.4(a)	0.92(a)
May 17, 1999	0.12(a)	0.26(a)	0.85(a)	0.38(a)
June 26, 1999	0.28(a)	0.51(a)	3.48(b)	1.24(a)
October 25, 1999	0.13(a)	0.21(a)	1.2(a)	0.92(a)

Different letters within a row denote significant difference between treatment groups on that date (α=0.05).

Seasonal rainfall also may have affected nutrient runoff concentrations. Nutrient runoff concentrations in the April 1998 and October 1998 from simulated rainfall events were higher than in later rainfall events. The increases in concentration appear to be related to the amount of natural rainfall. Nutrient concentration decreased in 1999, when there was more rainfall between the time of litter application and the first simulated rainfall.

Correlation of Soil Test Phosphorus with SRP in Runoff

Figure 19 shows the correlation of SRP in runoff with respect to STP in the top 0-5 cm (0-2 in.) of the soils. The coefficient of determination (R^2) indicates that STP explains about 33 percent of the variance in runoff SRP.

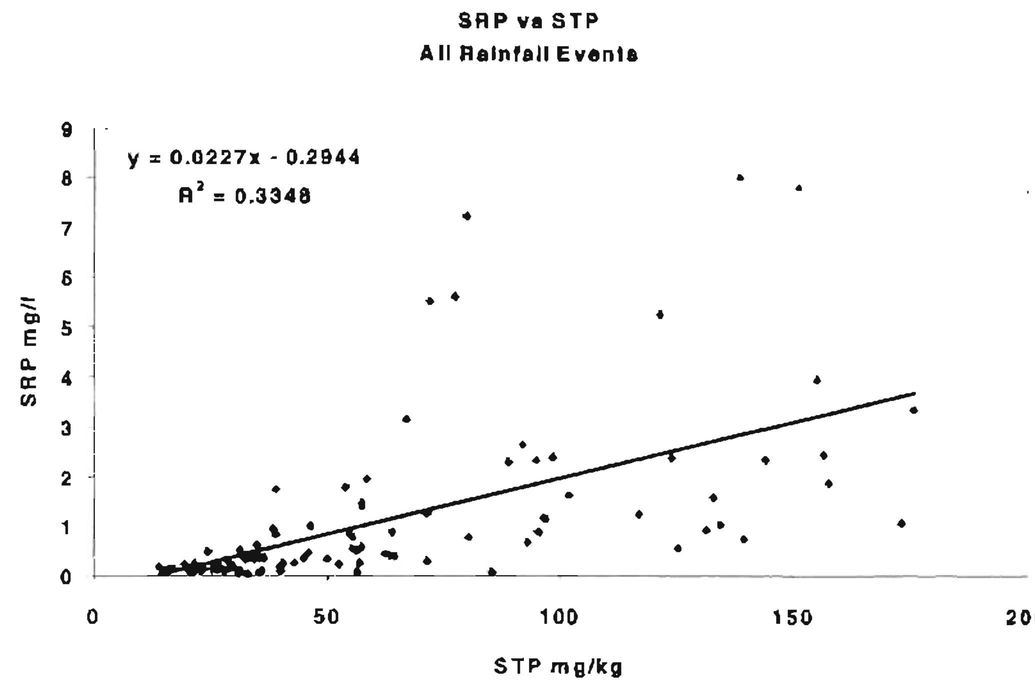

Figure 19. Soil Test Phosphorus vs. Soluble Reactive Phosphorus correlation at 0-5 cm (0-2 in.) for all rainfall events.

Regression of SRP vs. STP for the rainfall simulator events, one year after litter application (April 1998 and May 1999) shows a higher coefficient of determination (R^2=0.60)(Figure 20) compared to the regression including all data points. This suggests that when litter is present, runoff P is related to other factors such as application rate. However, one year after application, STP becomes very important. The R^2 indicates 60 percent of the variance is explained by the regression one year after litter application.

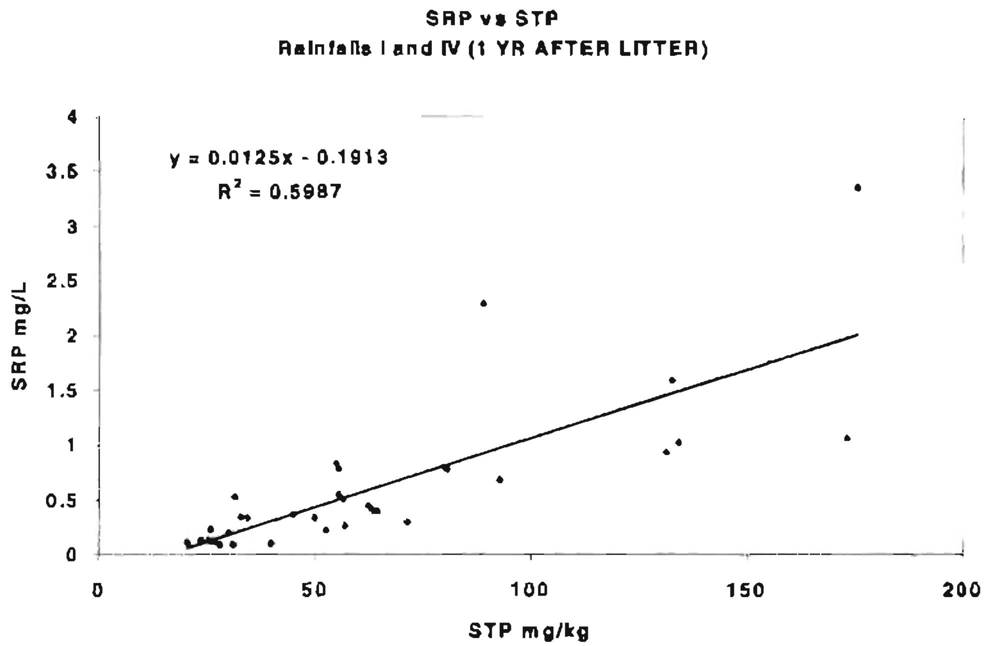

Figure 20. Soil Test Phosphorus vs. Soluble Reactive Phosphorus correlation at 0-5 cm (0-2 in.) one year after litter applications.

Grazing Management

Overall, my assessment provides significant information about how different nutrient management systems affect nutrient concentration in runoff. Under traditional management plans, poultry litter provides all nutrients for the grazing system. P-Based management reduced the amount of litter applied according to recommendations based on STP and phosphorus need of the forage crop (OSU Fact Sheet 2225). Commercial fertilizer is substituted for the remaining nitrogen needed to establish a realistic forage yield goal, considering all litter-N to be available.

This demonstration shows that by substituting commercial nitrogen fertilizer for poultry litter, soil test phosphorus will not buildup as rapidly, if at all, compared to the N-based management strategy. Under N-based manure application, however, STP can buildup to extremely high levels in a matter of only a few years.

Soluble reactive phosphorus in runoff from P-based management was lower than runoff from the N-based management (α=0.05), with plot 3 removed. Under P-based management, a lower mean SRP concentration was identifiable throughout all sampling dates except May 21, 1998 when litter was freshly applied to the surface. The demonstration shows that following a P-based management plan, runoff concentrations in surface runoff can be reduced.

Although the grazed control showed higher mean concentrations of nutrients in runoff throughout the project, there was no significant difference between control and negative control treatments with respect to N, P, or runoff volume on any sampling dates. Further research is needed to determine the effect of cattle on a sensitive grazing system.

CHAPTER VI

CONCLUSIONS

Runoff from four different nutrient management strategies was collected using simulated rainfall. Samples were analyzed for nitrate-N (NO_3-N), ammonium-N (NH_4-N), and soluble reactive phosphorus (SRP). This method, although labor intensive, was much more reliable and less time consuming than monitoring runoff under natural rainfall. This design was based on the ability to collect subsamples from treatments, repeatable throughout the experimental design.

N-based and P-based treatments received the same total rate of nitrogen. Soil test nitrate-N increased in both N-based and P-Based treatments immediately after application and declined through the year. Total nitrogen was the same, although the available N may have differed between sources. The soil nitrate-N levels declined more rapidly in the P-based treatment where ammonium nitrate was the principle source than in the N-based treatment where litter was the only source. This could lead to a recommendation to split the application of commercial fertilizer N in the P-based management system. Splitting application to late spring and late summer could both reduce N loss to runoff and improve utilization efficiency.

The N-based treatments, which received only poultry litter to meet the crops nutrient requirements, showed increased STP. The STP was not significantly elevated under the P-based management strategy. The application of poultry litter increased N-based treatment differences in soluble reactive phosphorus concentrations over the P-based management plan.

Correlation analysis showed a strong relationship between soil test phosphorus and runoff soluble reactive phosphorus. This suggests that control of soil test phosphorus may be important in reducing runoff soluble reactive phosphorus. In order to control soil test phosphorus, a P-based management strategy should be used. This study showed the P-based management strategies can be applied without any loss of forage production.

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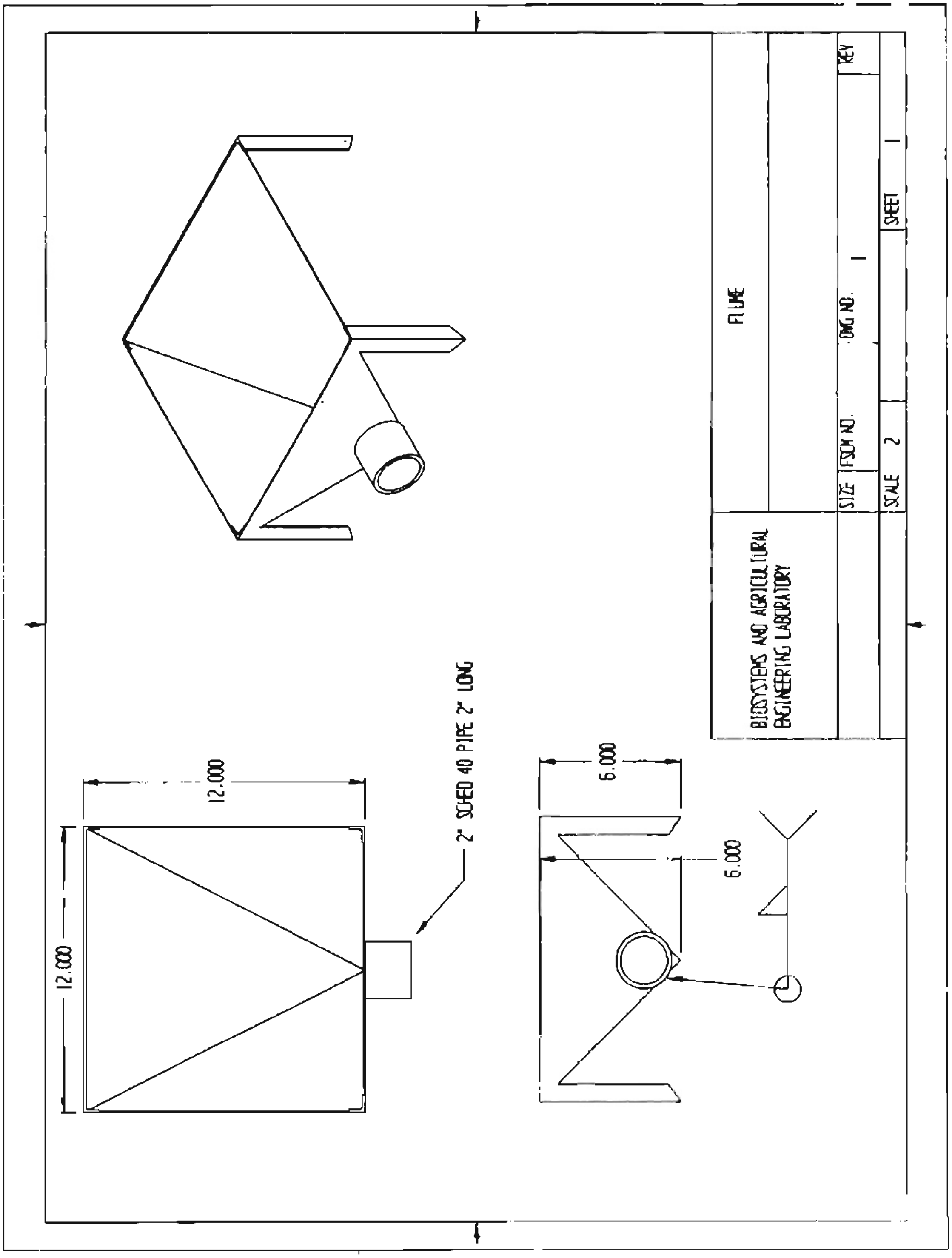
APPENDIX 1

FLUME DESIGN



APPENDIX 2

QUALITY ASSURANCE AND QUALITY CONTROL

A spike, duplicate and rainwater sample was submitted with the water samples from each rainfall simulation-runoff event. The spike solutions were obtained by splitting one randomly selected sample and adding a known amount of N and P. Duplicates were obtained by splitting one randomly selected sample. The rainwater samples were obtained directly from the rainfall simulator during the middle of each run. Spikes, duplicates and rainfall samples were sent to the laboratory along with regular samples. The tables below shows all values obtained from rainwater samples by treatment. The graphs displayed below show spike, duplicate and original samples.

Table 16. Rainwater samples from each treatment.

	N-Based			P-Based			Control			Negative Control		
	NO_3-N ppm	NH_4-N ppm	P ppm	NO_3-N ppm	NH_4-N ppm	P ppm	NO_3-N ppm	NH_4-N ppm	P ppm	NO_3-N ppm	NH_4-N ppm	P Ppm
Rainfall I												
Rainfall II	0.3	0	0	0.3	0	0	0.3	0	0	0.3	0.2	0
Rainfall III	5.68	0.26	0	5.75	0.22	0	5.68	0.25	0	5.71	0.34	0
Rainfall IV	0.38	0.23	0.06	0.39	0.18	0.04	0.35	0.54	0.05	0.37	0.23	0.05
Rainfall V	0.81	1.34	0.29	0.49	1.58	0.19	0.57	1.52	0.12	0.49	1.66	0.11
Rainfall VI	0.09	0.19	0.02	0.00	0.10	0.02	0.00	0.10	0.02	0.00	0.12	0.02

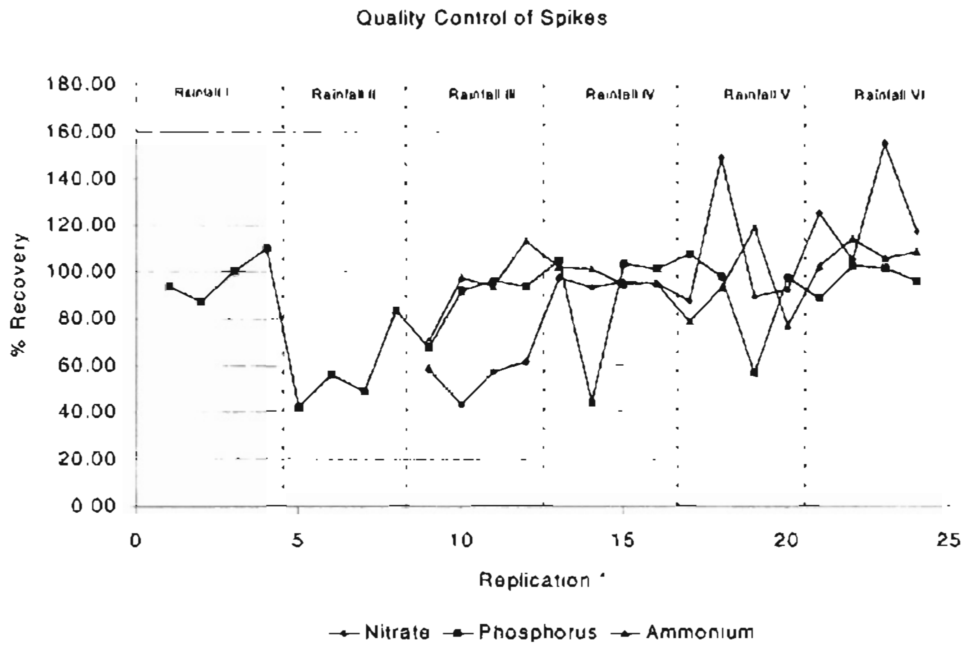


Figure 21. Quality control recovery of Soluble Reactive Phosphorus in spiked samples.

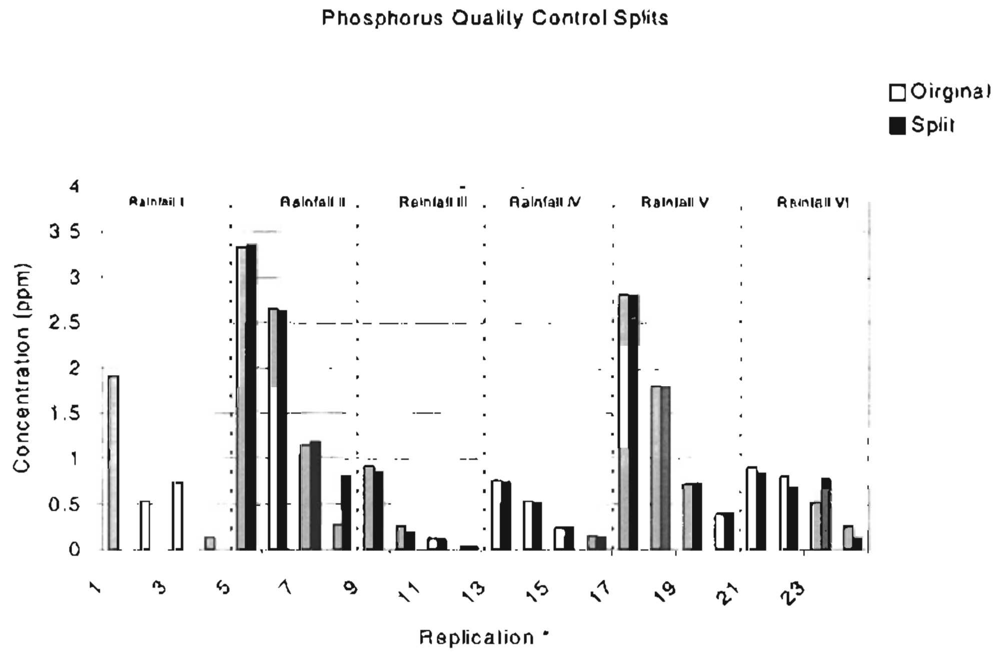


Figure 22. Quality control reproducibility of Soluble Reactive Phosphorus in split samples.

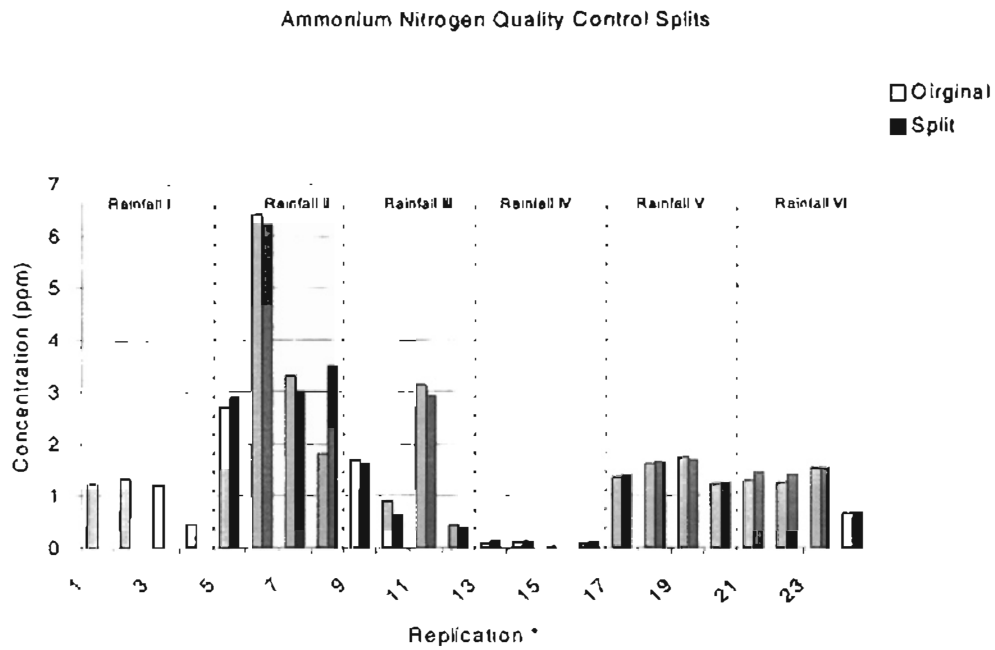


Figure 23. Quality control reproducibility of Ammonium-Nitrogen in split samples.

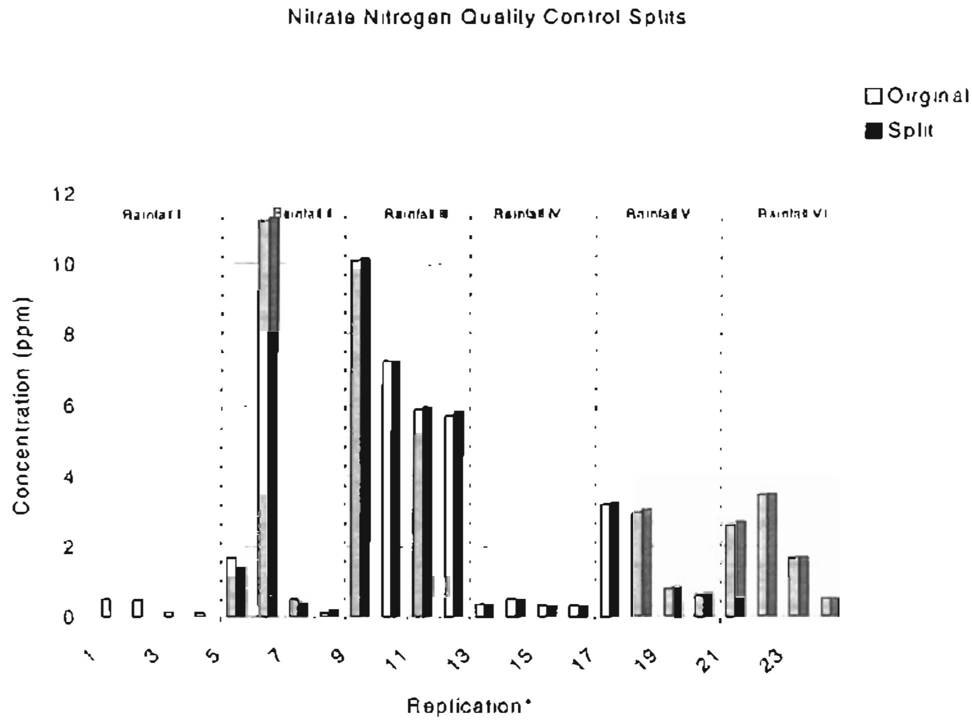


Figure 24. Quality control reproducibility of Nitrate-Nitrogen in split samples.

APPENDIX 3

RAINFALL INFORMATION

LeFlore Country Station Rainfalls in inches per hour.

	Mesonet	Heavener	Poteau	Average
Jan-98	1.49	8.45	7.05	5.7
Feb-98	3.3	3.92	3.88	3.7
Mar-98	6.04	6.23	6.94	6.4
Apr-98	1.32	1.31	1.89	1.5
May-98	5.11	5.1	5.66	5.3
Jun-98	2.14	1.73	1.631	1.8
Jul-98	0.59	0.84	2.45	1.3
Aug-98	0.96	1.77	0.39	1.0
Sep-98	7.35	6.06	7.36	6.9
Oct-98	5.76	5.87	5.55	5.7
Nov-98	3.23	2.8	3.81	3.3
Dec-98	3.49		3.50	3.5
Jan-99	1.96	2.1	2.01	2.0
Feb-99	1.54	1.5	1.58	1.5
Mar-99	6.62	5.88	6.77	6.4
Apr-99	3.58	3.29	4.11	3.7
May-99	8.9	8.08	9.15	8.7
Jun-99	9.25	5.47	9.58	8.1
Jul-99	0.4	2.02	1.78	1.4
Aug-99	0.26	1.26	1.20	0.9
Sep-99	2.36	2.45		2.4
Oct-99	1.81	1.81	1.86	1.8
Nov-99	1.32			1.3
Dec-99	5.08		4.77	4.9

Location	Latitude	Longitude	Elevation (ft)
Mesonet Site	34.5904N	94.4117W	469
Heavener-Coop	34.55N	94.36W	592
Poteau-Coop	35.3N	94.37W	440

APPENDIX 4

RUNOFF CONCENTRATIONS AND LOADS

Sample Coding System

Samples were coded according to rainfall event, plot number, replication number and sample number. Example: I1B5 and IV7A3 are identified in the table below.

Rainfall Event	Plot Number	Plot Side	Runoff Sample #
I	1	B	5
IV	7	A	3

Rainfall Event (CODE)	Rainfall Date
I	April 29, 1998
II	May 21, 1998
III	October 26, 1998
IV	May 17, 1999
V	June 26, 1999
VI	October 25, 1999

Sample Code	Ortho-P	NO3-N	NH4-N	Q	Time	Ortho-P	NO3-N	NH4-N
	mg/L			L/s	s	Load mg/s		
I1A1	2.17	0.47	2.26	0.028	630	0.062	0.013	0.064
I1A2	3.08	1.36	5.29	0.192	780	0.591	0.261	1.015
I1A3	3.33	0.73	7.09	0.392	930	1.306	0.286	2.780
I1A4	3.34	0.44	5.53	0.832	1230	2.778	0.366	4.599
I1A5	2.68	0.41	3.64	0.929	1530	2.488	0.381	3.380
I1A6	2.37	0.23	3.01	1.025	1830	2.428	0.236	3.084
I1A7	1.88	0.18	2.11	1.052	2430	1.977	0.189	2.219
I1A8	1.56	0.29	1.41	1.200	3030	1.872	0.348	1.692
I1B1	4.22	0.42	3.03	0.028	630	0.120	0.012	0.086
I1B2	5.61	0.67	3.41	0.192	780	1.077	0.129	0.655
I1B3	5.24	0.69	3.95	0.392	930	2.055	0.271	1.549
I1B4	4.35	0.5	3.89	0.805	1230	3.502	0.403	3.132
I1B5	3.81	0.55	3.36	0.920	1530	3.505	0.506	3.091
I1B6	3.36	0.27	2.96	0.966	1830	3.245	0.261	2.859
I1B7	2.84	0.21	2.74	1.058	2430	3.005	0.222	2.899
I1B8	2.49	0.27	2.17	1.101	3030	2.742	0.297	2.390
I2A1	1.09	0.76	2.44	0.011	540	0.012	0.009	0.028
I2A2	1.33	0.45	2.2	0.027	690	0.036	0.012	0.059
I2A3	1.31	0.75	1.69	0.170	960	0.223	0.127	0.287
I2A4	1.37	0.66	1.93	0.487	1260	0.667	0.321	0.940
I2A5	1.23	0.38	1.5	0.739	1560	0.908	0.281	1.108
I2A6	1	0.27	1.36	0.952	2160	0.952	0.257	1.295
I2A7	0.84	0.22	1.03	1.060	2760	0.890	0.233	1.092
I2B1	3.17	0.61	2.02	0.012	600	0.038	0.007	0.024
I2B2	3.01	0.47	1.79	0.026	750	0.080	0.012	0.047
I2B3	1.98	0.48	1.34	0.112	1020	0.222	0.054	0.150
I2B4	1.91	0.47	1.19	0.342	1320	0.654	0.161	0.408
I2B5	1.49	0.34	1.21	0.501	1620	0.746	0.170	0.606
I2B6	1.75	0.24	1.03	0.727	2220	1.272	0.174	0.749
I2B7	1.16	0.15	0.79	0.814	2820	0.944	0.122	0.643
I3A1	0.51	0.52	2.4	0.013	600	0.007	0.007	0.032
I3A2	0.56	0.85	2.55	0.034	750	0.019	0.029	0.086
I3A3	0.8	0.47	1.59	0.414	1050	0.331	0.194	0.658
I3A4	0.63	0.34	0.95	0.619	1350	0.390	0.210	0.588
I3A5	0.59	0.26	0.8	0.718	1650	0.424	0.187	0.575
I3A6	0.42	0.17	0.6	0.807	2250	0.339	0.137	0.484
I3A7	0.35	0.14	0.56	0.887	2850	0.310	0.124	0.496
I3B1	0.58	0.92	1.49	0.022	510	0.013	0.020	0.033
I3B2	0.53	0.7	1.53	0.028	660	0.015	0.020	0.043
I3B3	0.66	0.54	1.33	0.273	960	0.180	0.148	0.364
I3B4	0.5	0.26	0.94	0.525	1260	0.263	0.137	0.494
I3B5	0.42	0.2	0.9	0.637	1560	0.268	0.127	0.574
I3B6	0.34	0.16	0.69	0.776	2160	0.264	0.124	0.536
I3B7	0.3	0.12	0.73	0.845	2760	0.253	0.101	0.617
I4A1	0.65	2.04	1.7	0.026	450	0.017	0.053	0.044
I4A2	0.84	1.18	1.4	0.067	600	0.056	0.078	0.093
I4A3	0.88	0.54	1.3	0.185	900	0.163	0.100	0.240
I4A4	1.32	0.55	1.2	0.450	1200	0.595	0.248	0.541
I4A5	0.92	0.38	1.07	0.604	1500	0.556	0.230	0.646
I4A6	0.73	0.31	0.99	0.763	2100	0.557	0.237	0.755
I4A7	0.63	0.22	0.96	0.820	2700	0.517	0.180	0.787
I4B1	0.5	0.43	1.78	0.017	630	0.008	0.007	0.030
I4B2	0.51	0.28	1.38	0.121	780	0.062	0.034	0.167
I4B3	0.52	0.28	1.11	0.356	1080	0.185	0.100	0.395
I4B4	0.53	0.45	1.07	0.607	1380	0.322	0.273	0.649
I4B5	0.49	0.45	1.19	0.775	1680	0.380	0.349	0.922
I4B6	0.42	0.29	1.11	0.850	2280	0.357	0.247	0.944
I4B7	0.36	0.23	0.99	0.976	2880	0.351	0.224	0.966

Sample Code	Ortho-P	NO3-N	NH4-N	Q	Time	Ortho-P	NO3-N	NH4-N
		mg/L		L/s	s		Load mg/s	
I5A1	0.27	0.12	0.78	0.019	510	0.005	0.002	0.015
I5A2	0.25	0.11	0.55	0.020	660	0.005	0.002	0.011
I5A3	0.32	0.1	0.59	0.022	960	0.007	0.002	0.013
I5A4	0.29	0.09	0.67	0.027	1260	0.007	0.002	0.018
I5A5	0.27	0.08	0.34	0.119	1560	0.032	0.009	0.040
I5A6	0.22	0.09	0.54	1.750	2160	0.384	0.157	0.945
I5A7	0.23	0.08	0.47	0.445	2760	0.102	0.036	0.209
I5B1	0.56	0.09	0.59	0.004	840	0.002	0.000	0.002
I5B2	0.47	0.08	0.56	0.005	990	0.002	0.000	0.003
I5B3	0.38	0.08	0.57	0.019	1290	0.007	0.001	0.011
I5B4	0.3	0.08	0.48	0.060	1590	0.018	0.005	0.029
I5B5	0.3	0.08	0.73	0.114	1890	0.034	0.009	0.083
I5B6	0.27	0.07	0.56	0.196	2490	0.052	0.014	0.110
I5B7	0.23	0.06	0.38	0.445	3090	0.102	0.027	0.169
I6A1	0.81	0.17	1.01	0.012	510	0.009	0.002	0.012
I6A2	0.91	0.13	0.85	0.088	660	0.080	0.011	0.075
I6A3	0.57	0.1	0.66	0.175	960	0.099	0.017	0.115
I6A4	0.45	0.08	0.71	0.252	1260	0.113	0.020	0.179
I6A5	0.35	0.08	0.56	0.305	1560	0.106	0.024	0.171
I6A6	0.27	0.11	0.54	0.419	2160	0.113	0.046	0.226
I6A7	0.21	0.07	0.69	0.495	2760	0.103	0.035	0.342
I6B1	1.56	0.21	5.81	0.023	390	0.035	0.005	0.132
I6B2	1.16	0.15	1.98	0.196	540	0.227	0.029	0.388
I6B3	0.85	0.12	1.72	0.301	840	0.255	0.036	0.517
I6B4	0.73	0.1	1.33	0.433	1140	0.315	0.043	0.575
I6B5	0.56	0.09	0.94	0.516	1440	0.288	0.046	0.485
I6B6	0.41	0.09	0.91	0.655	2040	0.268	0.059	0.596
I6B7	0.34	0.09	0.73	0.780	2640	0.265	0.070	0.570
I7A1	0.19	0.12	0.89	0.013	1980	0.002	0.002	0.011
I7A2	0.22	0.1	0.67	0.193	2130	0.042	0.019	0.129
I7A3	0.14	0.08	0.53	0.478	2430	0.066	0.038	0.254
I7A4	0.1	0.08	0.45	0.595	2730	0.059	0.048	0.268
I7A5	0.1	0.06	0.36	0.641	3030	0.064	0.038	0.231
I7A6	0.08	0.06	0.35	0.804	3630	0.064	0.048	0.281
I7A7	0.08	0.06	0.43	0.985	4230	0.077	0.059	0.423
I7B1	0.19	0.12	0.62	0.013	1140	0.002	0.002	0.008
I7B2	0.25	0.09	0.64	0.059	1290	0.014	0.005	0.038
I7B3	0.82	0.08	0.59	0.257	1590	0.210	0.021	0.152
I7B4	0.54	0.08	0.4	0.557	1890	0.302	0.045	0.223
I7B5	0.41	0.06	0.34	0.732	2190	0.300	0.044	0.249
I7B6	0.25	0.07	0.21	0.901	2790	0.225	0.063	0.189
I7B7	0.21	0.06	0.18	0.837	3390	0.175	0.050	0.151
I8A1	0.17	0.1	0.89	0.007	660	0.001	0.001	0.006
I8A2	0.16	0.09	0.73	0.009	810	0.001	0.001	0.007
I8A3	0.13	0.1	0.75	0.016	1110	0.002	0.002	0.012
I8A4	0.14	0.08	0.74	0.072	1410	0.010	0.006	0.054
I8A5	0.13	0.08	0.57	0.151	1710	0.019	0.012	0.086
I8A6	0.1	0.07	0.7	0.489	2310	0.048	0.034	0.342
I8A7	0.07	0.07	0.48	0.717	2910	0.050	0.050	0.344
I8B1	0.11	0.1	0.89	0.005	1080	0.001	0.000	0.004
I8B2	0.11	0.09	0.86	0.007	1230	0.001	0.001	0.006
I8B3	0.15	0.14	0.84	0.019	1530	0.002	0.003	0.016
I8B4	0.16	0.12	0.51	0.243	1830	0.038	0.029	0.124
I8B5	0.12	0.09	0.4	0.528	2130	0.063	0.048	0.211
I8B6	0.09	0.08	0.4	0.889	2730	0.08	0.071	0.356
I8B7	0.07	0.06	0.26	0.943	3330	0.066	0.057	0.245

Sample Code	Ortho-P	NO3-N	NH4-N	Q	Time	Ortho-P	NO3-N	NH4-N
		mg/L		L/s	s		Load mg/s	
II1A1	6.83	15.2	6.7	0.026	0.359	420	0.178	0.395
II1A2	9.42	22.5	8.8	0.324	0.361	570	3.049	7.282
II1A3	10.17	13.4	7.7	0.786	0.364	870	7.998	10.539
II1A4	9.67	5.7	4.3	0.797	0.368	1170	7.708	4.544
II1A5	9.25	4	4	0.735	0.371	1470	6.796	2.939
II1A6	8.42	3.4	4.4	0.770	0.378	2070	6.482	2.617
II1A7	0.78	2.5	4.1	0.746	0.385	2670	0.582	1.865
II1B1	6.17	9.5	4.5	0.046	0.359	420	0.284	0.437
II1B2	8.42	17.2	5.2	0.188	0.361	570	1.579	3.225
II1B3	8.75	11.3	4.7	0.751	0.364	870	6.572	8.487
II1B4	8.67	5.7	4 6	0.745	0.368	1170	6 463	4.249
II1B5	7.92	3.9	4.7	0.756	0.371	1470	5.986	2.948
II1B6	7.33	2.1	4.2	0.717	0.378	2070	5.258	1.506
II1B7	6.67	1.3	4	0.722	0.385	2670	4.816	0.939
II2A1	2.83	1.9	3.4	0.007	0.403	300	0.019	0 012
II2A2	3.83	4.9	3.8	0.033	0.405	450	0.125	0.160
II2A3	3.75	2.6	3.6	0.236	0.408	750	0.884	0.613
II2A4	3	1.5	3	0.402	0.412	1050	1.207	0.604
II2A5	2.58	1.1	2.7	0.505	0.415	1350	1.303	0.556
II2A6	2	0.7	2.5	0.596	0.422	1950	1.192	0.417
II2A7	1.75	0.6	2.7	0.742	0.429	2550	1.299	0.445
II2B1	3.5	2.4	3.4	0.017	0.404	360	0.060	0.041
II2B2	3.83	0.9	2.9	0.103	0.406	510	0.393	0.092
II2B3	3.5	1.4	2.7	0.294	0.409	810	1.029	0.411
II2B4	3.33	1.7	2.7	0.312	0.413	1110	1.039	0.530
II2B5	2.92	1	2.6	0.337	0.416	1410	0.985	0.337
II2B6	2.25	0.8	2.5	0.405	0.423	2010	0.910	0.324
II2B7	1.92	0.5	2.3	0.533	0.430	2610	1.024	0.267
II3A1	3.17	23	8.1	0.019	0.453	390	0.059	0.427
II3A2	7.42	28.3	7.5	0.304	0.455	540	2.255	7.994
II3A3	6.92	12.9	6.3	0.505	0.458	840	3.493	6.512
II3A4	6.42	9.4	5.9	0.511	0.462	1140	3.282	4.806
II3A5	5.83	6.9	5.7	0.576	0.465	1440	3.357	3.974
II3A6	5	4.8	5.2	0.587	0.472	2040	2.936	2.819
II3A7	4.25	3.6	4.6	0.713	0.479	2640	3.031	2.568
II3B1	11.31	36.8	10.4	0.015	0.453	420	0.167	0.545
II3B2	9.95	26.4	8.1	0.149	0.455	570	1.481	3.929
II3B3	8.98	15	7.3	0.461	0.459	870	4.136	6.909
II3B4	8.38	9.5	6.7	0.478	0.462	1170	4.007	4.542
II3B5	7.65	6.5	5.8	0.513	0.466	1470	3.924	3.334
II3B6	6.46	3.9	5.4	0.585	0.473	2070	3.781	2.283
II3B7	5.54	2.8	5.3	0.654	0.480	2670	3.621	1.830
II4A1	0.7	10.7	5.6	0.008	0.505	630	0.006	0.085
II4A2	2.78	15.7	6.9	0.030	0.507	780	0.082	0.463
II4A3	2.9	11.8	6.2	0.087	0.510	1080	0.252	1.025
II4A4	2.43	8.8	6.1	0.096	0.514	1380	0.234	0.849
II4A5	2	6.9	5.2	0.136	0.517	1680	0.272	0.938
II4A6	1.52	4.1	4.2	0.221	0.524	2280	0.336	0.907
II4A7	1.27	3.4	3.7	0.285	0.531	2880	0 362	0.969
II4B1	2.01	17.8	8.5	0.013	0.503	510	0.026	0.228
II4B2	1.63	13.2	7.5	0.074	0.505	660	0.121	0.977
II4B3	2.36	12	6.9	0.192	0.509	960	0.454	2.306
II4B4	2.65	11.2	6 4	0.252	0.512	1260	0.667	2.819
II4B5	2.55	8.7	5.7	0.292	0.516	1560	0.744	2.539
II4B6	2.4	6.2	5.6	0.384	0.523	2160	0.923	2.384
II4B7	2.18	4.3	4.4	0.468	0.530	2760	1 020	2.011

Sample Code	I Ortho-P	NO3-N	NH4-N	Q	Time	Ortho-P	NO3-N	NH4-N
	mg/L			L/s	s	Load mg/s		
II5A1	2.33	0.2	2.2	0.006	0.592	360	0.014	0.001
II5A2	1.41	0.2	2.1	0.007	0.593	510	0.011	0.001
II5A3	0.87	0.2	1.8	0.010	0.597	810	0.009	0 002
II5A4	0.6	0.2	1.9	0.011	0.601	1170	0.007	0.002
II5A5	0.49	0.1	1.8	0.009	0.605	1470	0.005	0.001
II5A6	0.32	0.1	1.7	0.012	0.611	2070	0.004	0.001
II5A7	0.35	0.2	1.2	0.186	0.618	2670	0.065	0.037
II5B1	0.56	0.09	0.59	0.002	0.594	600	0.001	0.000
II5B2	0.47	0.08	0.56	0.002	0.599	1020	0.001	0.000
II5B3	0.38	0.08	0.57	0.002	0.603	1380	0.001	0.000
II5B4	0.3	0.08	0.48	0.002	0.607	1680	0.001	0.000
II5B5	0.3	0.08	0.73	0.009	0.614	2280	0.003	0.001
II5B6	0.27	0.07	0.56	0.124	0.621	2880	0.033	0.009
II5B7	0.23	0.06	0.38	0.433	0.628	3480	0.100	0 026
II6A1	1.09	0.1	2.1	0.011	0.684	1950	0.012	0.001
II6A2	0.83	0.1	1.7	0.067	0.686	2100	0.056	0.007
II6A3	0.29	0.1	1.7	0.182	0.690	2400	0.053	0.018
II6A4	0.22	0.2	1.9	0.315	0.693	2700	0.069	0.063
II6A5	0.26	0.1	1.7	0.403	0.697	3000	0.105	0.040
II6A6	0.18	0.1	1.8	0.585	0.703	3600	0.105	0.058
II6A7	0.07	0.1	1.6	0.726	0.710	4200	0 051	0.073
II6B1	2.89	1.7	4	0.033	0.668	510	0.096	0.056
II6B2	2.31	0.8	4.3	0.114	0.669	660	0.262	0.091
II6B3	1.69	0.4	3.4	0.102	0.673	960	0.172	0.041
II6B4	1.14	0.5	3 3	0.094	0.676	1260	0.107	0 047
II6B5	1.03	0.2	2.9	0.095	0.680	1560	0.098	0.019
II6B6	0.62	0.2	2.4	0.315	0.687	2160	0.195	0.063
II6B7	0.45	0.2	2.2	0.417	0.694	2760	0.187	0.083
II7A1	0.48	0.1	1.6	0.034	0.755	2730	0.016	0.003
II7A2	0.39	0.1	1.7	0.278	0.757	2880	0.108	0.028
II7A3	0.18	0.1	1.4	0.455	0.760	3180	0.082	0.045
II7A4	0.19	0.1	1.4	0.571	0.764	3480	0.109	0.057
II7A5	0.16	0.1	1.4	0.588	0.767	3780	0.094	0.059
II7A6	0.03	0.1	1.3	0.772	0.774	4380	0.023	0.077
II7A7	0.01	0.1	1.3	0.912	0.781	4980	0.009	0 091
II7B1	0 39	0.1	1.9	0.008	0 740	1440	0.003	0 001
II7B2	0.56	0.1	2	0.021	0.742	1590	0.012	0 002
II7B3	0.48	0.1	1.5	0.147	0.745	1890	0.070	0.015
II7B4	0.41	0.1	1.6	0.413	0.749	2190	0.169	0.041
II7B5	0.33	0.2	1.3	0.661	0.752	2490	0.218	0.132
II7B6	0.23	0.1	1.3	0.919	0.759	3090	0.211	0.092
II7B7	0.2	0.1	1.4	1.032	0.766	3690	0.206	0 103
II8A1	0.32	0.2	3.2	0.006	0.818	1740	0.002	0.001
II8A2	0.25	0.4	3.7	0.008	0.820	1890	0.002	0.003
II8A3	0.21	0.4	3.8	0.025	0.824	2190	0.005	0.010
II8A4	0.27	0.1	1.8	0.325	0.827	2490	0.088	0.032
II8A5	0.19	0.1	1.6	0.524	0.831	2790	0.099	0.052
II8A6	0.13	0	1 4	0.803	0.838	3390	0 104	0.000
II8A7	0.06	0.1	1 4	0.913	0.844	3990	0.055	0.091
II8B1	0.76	0.1	3.2	0.006	0.819	1770	0.005	0.001
II8B2	0.38	0.1	1.6	0.016	0.820	1920	0.006	0 002
II8B3	0.3	0.1	1.5	0.275	0.824	2220	0.082	0.027
II8B4	0.19	0.1	1.2	0.617	0.827	2520	0.117	0.062
II8B5	0.18	0.1	1.3	0.780	0.831	2820	0.140	0 078
II8B6	0.12	0.1	1.2	0.918	0.838	3420	0.110	0.092
II8B7	0.3	0.1	1.2	1.055	0.845	4020	0.317	0.106

Sample Code	I Ortho-P	NO3-N	NH4-N	Q	Time	Ortho-P	NO3-N	NH4-N
	mg/L			L/s	s	Load mg/s		
III1A1	1.28	8.38	1.52	0.011	0.330	540	0.014	0.092
III1A2	1.12	7.82	0.93	0.020	0.332	690	0.022	0.153
III1A3	2.55	9.7	1.08	0.212	0.335	990	0.540	2.054
III1A4	2.62	7.85	1.27	0.433	0.339	1290	1.134	3.398
III1A5	2.29	7.32	0.9	0.652	0.342	1590	1.492	4.770
III1A6	1.59	6.51	0.74	0.741	0.349	2190	1.179	4.826
III1A7	1.25	6.15	0.67	0.670	0.356	2790	0.838	4.123
III1B1	2.08	9.1	9.1	0.006	0.330	540	0.012	0.051
III1B2	3.15	9.9	9.9	0.030	0.332	690	0.093	0.293
III1B3	4.4	10.11	10.11	0.254	0.335	990	1.119	2.570
III1B4	3.38	8.52	8.52	0.525	0.339	1290	1.773	4.469
III1B5	2.8	7.75	7.75	0.653	0.342	1590	1.827	5.057
III1B6	2.04	6.78	6.78	0.757	0.349	2190	1.544	5.132
III1B7	1.5	6.27	6.27	0.776	0.356	2790	1.165	4.868
III2A1	0.08	6.72	0.76	0.008	0.393	540	0.001	0.053
III2A2	0.08	7.01	0.67	0.010	0.395	690	0.001	0.067
III2A3	0.08	10.46	1.96	0.231	0.399	960	0.018	2.414
III2A4	1	14.58	2.66	0.516	0.402	1260	0.516	7.527
III2A5	0.79	12.72	2.04	0.670	0.406	1560	0.529	8.525
III2A6	0.47	8.93	1.68	0.745	0.413	2160	0.350	6.654
III2A7	0.33	7.42	1.5	0.937	0.419	2760	0.309	6.954
III2B1	0.21	7.46	0.95	0.014	0.400	1140	0.003	0.108
III2B2	1.83	14.52	1.94	0.153	0.401	1290	0.281	2.227
III2B3	1.31	13.35	1.97	0.463	0.405	1590	0.607	6.186
III2B4	0.92	10.13	1.7	0.597	0.408	1890	0.549	6.044
III2B5	0.81	8.77	1.5	0.673	0.412	2190	0.545	5.906
III2B6	0.51	7.31	1.11	0.821	0.419	2790	0.419	5.999
III2B7	0.58	6.92	0.96	1.063	0.426	3390	0.617	7.358
III3A1	0.09	6.72	0.82	0.007	0.453	720	0.001	0.050
III3A2	0.59	7.51	1.08	0.016	0.455	870	0.009	0.118
III3A3	1.46	8.59	1.17	0.043	0.458	1170	0.062	0.367
III3A4	1.53	8.89	1.31	0.214	0.461	1470	0.327	1.901
III3A5	2.23	8.6	1.24	0.363	0.465	1770	0.810	3.125
III3A6	1.25	7.27	1.04	0.613	0.472	2370	0.767	4.460
III3A7	1.06	6.76	0.85	0.917	0.479	2970	0.972	6.199
III3B1	0.82	7.37	1.12	0.005	0.453	720	0.004	0.037
III3B2	1.59	7.75	1.38	0.142	0.455	870	0.226	1.100
III3B3	2.2	8.14	1.45	0.330	0.458	1170	0.725	2.684
III3B4	1.57	7.3	1.25	0.402	0.461	1470	0.631	2.932
III3B5	1.45	6.81	1.14	0.464	0.465	1770	0.673	3.163
III3B6	0.96	6.31	0.94	0.543	0.472	2370	0.522	3.429
III3B7	0.66	6.02	0.98	0.568	0.479	2970	0.375	3.419
III4A1	0.13	6.98	0.74	0.013	0.507	1050	0.002	0.088
III4A2	0.06	6.95	0.73	0.019	0.509	1200	0.001	0.133
III4A3	0.19	6.52	0.72	0.053	0.513	1500	0.010	0.349
III4A4	0.06	6.07	0.58	0.181	0.516	1800	0.011	1.100
III4A5	0.11	6.49	0.53	0.517	0.519	2100	0.057	3.358
III4A6	0.03	6.15	0.48	0.730	0.526	2700	0.022	4.487
III4A7	0.05	6.01	0.42	0.952	0.533	3300	0.048	5.724
III4B1	0.08	6.43	1.07	0.009	0.506	930	0.001	0.060
III4B2	0.03	6.34	0.79	0.023	0.508	1080	0.001	0.148
III4B3	0.03	6.52	0.83	0.147	0.511	1380	0.004	0.957
III4B4	0.26	7.24	0.9	0.267	0.515	1680	0.069	1.935
III4B5	0.14	6.84	0.84	0.377	0.518	1980	0.053	2.576
III4B6	0.1	6.59	0.74	0.779	0.525	2580	0.078	5.136
III4B7	6	6.4	0.64	1.006	0.532	3180	6.036	6.439

Sample Code	Ortho-P	NO3-N	NH4-N	Q	Time	Ortho-P	NO3-N	NH4-N
	mg/L			L/s	s	Load mg/s		
III5A1	0.03	5.77	0.7	0.009	0.070	2070	0.000	0.051
III5A2	0.26	6.01	0.72	0.160	0.072	2220	0.042	0.961
III5A3	0.31	6.11	0.79	0.398	0.075	2520	0.124	2.434
III5A4	0.29	5.96	0.72	0.591	0.078	2820	0.171	3.521
III5A5	0.32	5.84	0.69	0.742	0.082	3120	0.238	4.336
III5A6	0.29	5.8	0.57	0.859	0.089	3720	0.249	4.983
III5A7	0.1	5.82	0.52	1.117	0.096	4320	0.112	6.503
III5B1	0.07	7.13	0.87	0.015	0.069	1980	0.001	0.110
III5B2	0.06	7.67	1.27	0.090	0.070	2130	0.005	0.690
III5B3	0.07	6.67	0.74	0.394	0.074	2430	0.028	2.626
III5B4	0.14	6.33	0.62	0.619	0.077	2730	0.087	3.921
III5B5	0.05	6.26	0.52	0.821	0.081	3030	0.041	5.142
III5B6	0.06	6.24	0.45	1.114	0.088	3630	0.067	6.949
III5B7	0.08	6.04	0.38	1.145	0.095	4230	0.092	6.919
III6A1	0.05	6.11	0.24	0.022	0.130	1050	0.001	0.135
III6A2	0.1	6.01	0.56	0.080	0.132	1200	0.008	0.479
III6A3	0.1	6.02	0.31	0.139	0.135	1500	0.014	0.836
III6A4	0.12	5.96	0.26	0.284	0.139	1800	0.034	1.694
III6A5	0.11	5.88	0.2	0.432	0.142	2100	0.047	2.538
III6A6	0.1	5.91	0.19	0.642	0.149	2700	0.064	3.796
III6A7	0.08	5.92	0.16	1.105	0.156	3300	0.088	6.541
III6B1	0.04	5.91	0.7	0.011	0.123	390	0.000	0.065
III6B2	0.02	5.86	0.67	0.022	0.124	540	0.000	0.127
III6B3	0.1	6.08	0.99	0.092	0.128	840	0.009	0.562
III6B4	0.12	5.88	3.14	0.160	0.131	1140	0.019	0.942
III6B5	0.09	5.85	2.18	0.432	0.135	1440	0.039	2.525
III6B6	0.1	5.85	0.99	0.487	0.142	2040	0.049	2.852
III6B7	0.13	5.81	0.64	0.862	0.149	2640	0.112	5.006
III7A1	0.1	7.45	2.12	0.812	0.216	2910	0.081	6.052
III7A2	0.09	5.99	0.9	0.958	0.218	3060	0.086	5.738
III7A3	0.04	5.78	0.55	1.122	0.222	3360	0.045	6.483
III7A4	0.02	5.77	0.42	1.142	0.225	3660	0.023	6.591
III7A5	0 1	5.71	0.4	1.220	0.228	3960	0.122	6.963
III7A6	0.12	5.68	0.32	1.280	0.235	4560	0.154	7.268
III7A7	0.19	5.72	0 3	1.287	0.242	5160	0.245	7.362
III7B1	0.02	5.69	0.47	0.055	0.213	2610	0.001	0.314
III7B2	0 06	5.67	0.55	0.876	0.215	2760	0.053	4.965
III7B3	0.06	5.8	0.48	1.319	0.218	3060	0.079	7.652
III7B4	0.04	5.75	0.41	1.419	0.222	3360	0.057	8.162
III7B5	0.05	5.67	0.43	1.413	0.225	3660	0.071	8.014
III7B6	0.02	5.6	0.38	1.560	0.232	4260	0.031	8.736
III7B7	0.03	5.69	0.55	1.515	0.239	4860	0.045	8.621
III8A1	0.02	5.62	0.4	0.006	0.378	1620	0.000	0.034
III8A2	0.02	5.64	0.35	0.012	0.380	1770	0.000	0.069
III8A3	0.02	5.64	0.42	0.042	0.383	2070	0.001	0.236
III8A4	0.04	5.71	0.42	0.652	0.387	2370	0.026	3.721
III8A5	0.04	5.57	0.38	0.777	0.390	2670	0.031	4.328
III8A6	0.04	5.62	0.29	1.249	0.397	3270	0.050	7.021
III8A7	0.06	5.6	0.3	1.176	0.404	3870	0.071	6.584
III8B1	0.04	5.81	0.38	0.034	0.387	2400	0.001	0.196
III8B2	0.05	5.71	0.44	0.195	0.389	2550	0.010	1.116
III8B3	0.18	5.63	0.38	0.810	0.392	2850	0.146	4.559
III8B4	0.18	5.68	0.31	1.082	0.396	3150	0.195	6.144
III8B5	0.11	5.71	0.27	1.199	0.399	3450	0.132	6.847
III8B6	0.09	5.69	0.25	1.322	0.406	4050	0.119	7.521
III8B7	0.06	5 67	0.25	1.450	0.413	4650	0.087	8.223

Sample Code	I Ortho-P	NO3-N	NH4-N	Q	Time	Ortho-P	NO3-N	NH4-N
		mg/L		L/s	s		Load mg/s	
IV1A1	0.60	0.48	0.29	0.008	420	0.005	0.004	0.002
IV1A2	1.31	0.38	0.31	0.063	570	0.083	0.024	0.020
IV1A3	1.73	0.40	0.22	1.007	870	1.746	0.407	0.219
IV1A4	1.02	0.37	0.11	1.254	1170	1.277	0.458	0.140
IV1A5	0.64	0.34	0.18	1.163	1470	0 746	0.397	0.214
IV1A6	0.84	0.34	0.10	1.190	2070	0.998	0.406	0.115
IV1A7	0.72	0.31	0.11	1.134	2670	0.812	0.353	0.121
IV1B1	0.76	0.97	0.48	0.010	420	0.008	0.010	0.005
IV1B2	0.94	0.75	0.4	0.044	570	0.042	0.033	0.018
IV1B3	1.61	0.51	0.26	0.948	870	1.526	0.483	0.246
IV1B4	1.33	0.38	0.11	1.251	1170	1.664	0.475	0 138
IV1B5	1.07	0.47	0.11	1.322	1470	1.414	0.621	0 145
IV1B6	0.91	0.37	0.08	1.357	2070	1.235	0.502	0.109
IV1B7	0.5	0.36	0.08	1.319	2670	0.660	0.475	0.106
IV2A1	0.66	0.41	0.14	0.010	540	0.007	0.004	0.001
IV2A2	0.71	0.45	0.15	0.096	690	0.068	0.043	0.014
IV2A3	0.94	1.44	0.48	0.939	960	0.883	1.352	0.451
IV2A4	1.02	0.73	0.29	1.227	1260	1.252	0.896	0.356
IV2A5	0.84	0.81	0.24	1.271	1560	1.067	1.029	0.305
IV2A6	0.74	0.5	0.21	1.249	2160	0.924	0.625	0.262
IV2A7	0.42	0.42	0.21	1.240	2760	0.521	0.521	0.260
IV2B1	1.12	0.71	0.24	0.029	780	0.032	0.020	0.007
IV2B2	1.09	0.48	0.24	0.643	930	0.701	0.309	0.154
IV2B3	0.83	0.38	0.14	1.121	1230	0.930	0.426	0.157
IV2B4	0.75	0.37	0.09	1.217	1530	0.913	0.450	0.110
IV2B5	0.66	0.39	0.15	1.304	1830	0.860	0.508	0.196
IV2B6	0.58	0.36	0.1	1.271	2430	0.737	0.457	0.127
IV2B7	0.51	0.31	0.1	1.278	3030	0.652	0.396	0.128
IV3A1	0.5	0.38	0.15	0.048	360	0.024	0.018	0.007
I3VA2	0.68	0.43	0.19	0.025	510	0.017	0.011	0.005
IV3A3	1.38	0.42	0.16	0.632	810	0.871	0.265	0.101
IV3A4	0.99	0.38	0.15	1.038	1110	1.028	0.394	0.156
IV3A5	0.83	0.36	0.12	1.174	1410	0.975	0.423	0.141
IV3A6	0.69	0.32	0.11	1.199	2010	0.827	0.384	0.132
IV3A7	0.38	0.39	0.07	1.200	2610	0.456	0 468	0.084
IV3B1	0.54	0.35	0.09	0.007	360	0.004	0.002	0.001
IV3B2	0.97	0.47	0.15	0.021	510	0.020	0.010	0.003
IV3B3	0.88	0.4	0.16	0.655	810	0.576	0.262	0 105
IV3B4	0.77	0.37	0.09	1.136	1110	0.875	0.420	0.102
IV3B5	0.69	0 34	0.1	1.254	1410	0.865	0.426	0 125
IV3B6	0.32	0.32	0.11	1.224	2010	0.392	0.392	0 135
IV3B7	0.38	0.32	0.07	1.240	2610	0.471	0.397	0.087
I4VA1	0.31	0.36	0.14	0.046	600	0.014	0.017	0.006
IV4A2	0.39	0.56	0.17	0.161	750	0.063	0.090	0.027
IV4A3	0.51	0.35	0.19	0.816	1050	0.416	0.286	0.155
IV4A4	0.47	0.3	0.04	0.977	1350	0.459	0.293	0.039
IV4A5	0.38	0.35	0.09	1.021	1650	0.388	0.357	0.092
IV4A6	0.3	0.34	0.07	1.112	2250	0.334	0.378	0.078
IV4A7	0.25	0.31	0.07	1.176	2850	0.294	0 365	0.082
IV4B1	0.34	0.36	0.16	0.017	720	0.006	0 006	0.003
IV4B2	0.34	0.37	0.14	0.152	870	0.052	0.056	0.021
IV4B3	0.3	0.48	0.18	0.614	1170	0.184	0.295	0.111
IV4B4	0.53	0.52	0.1	0.736	1470	0.390	0.383	0.074
IV4B5	0.47	0.43	0.08	0.790	1770	0.371	0.340	0.063
IV4B6	0.39	0.36	0.09	0.903	2370	0.352	0.325	0 081
IV4B7	0.34	0.29	0.07	1.038	2970	0.353	0.301	0.073

Sample Code	Ortho-P	NO3-N	NH4-N	Q	Time	Ortho-P	NO3-N	NH4-N
	mg/L			L/s	s	Load mg/s		
IV5A1	0.54	0.33	0.25	0.015	600	0.008	0.005	0.004
IV5A2	0.42	0.3	0.24	0.246	750	0.103	0.074	0.059
IV5A3	0.33	0.29	0.14	0.569	1050	0.188	0.165	0.080
IV5A4	0.31	0.27	0.16	0.814	1350	0.252	0.220	0.130
IV5A5	0.3	0.3	0.1	1.074	1650	0.322	0.322	0.107
IV5A6	0.28	0.28	0.08	1.225	2250	0.343	0.343	0.098
IV5A7	0.25	0.28	0.07	1.296	2850	0.324	0.363	0.091
IV5B1	0.6	0.3	0.17	0.010	600	0.006	0.003	0.002
IV5B2	0.62	0.29	0.19	0.087	750	0.054	0.025	0.017
IV5B3	0.48	0.26	0.15	0.336	1050	0.161	0.087	0.050
IV5B4	0.45	0.25	0.13	0.536	1350	0.241	0.134	0.070
IV5B5	0.36	0.26	0.13	1.021	1650	0.368	0.266	0.133
IV5B6	0.31	0.35	0.08	1.300	2250	0.403	0.455	0.104
IV5B7	0.27	0.34	0.09	1.296	2850	0.350	0.441	0.117
IV6A1	1.03	0.33	0.21	0.043	570	0.044	0.014	0.009
IV6A2	0.36	0.33	0.16	0.299	720	0.107	0.099	0.048
IV6A3	0.27	0.32	0.07	0.880	1020	0.238	0.282	0.062
IV6A4	0.21	0.3	0.07	0.975	1320	0.205	0.293	0.068
IV6A5	0.2	0.3	0.08	1.075	1620	0.215	0.322	0.086
IV6A6	0.17	0.27	0.07	1.103	2220	0.188	0.298	0.077
IV6A7	0.15	0.3	0.06	1.199	2820	0.180	0.360	0.072
IV6B1	0.57	0.34	0.15	0.010	510	0.005	0.003	0.001
IV6B2	0.52	0.53	0.13	0.350	660	0.182	0.186	0.046
IV6B3	0.32	0.35	0.1	1.092	960	0.349	0.382	0.109
IV6B4	0.25	0.33	0.02	1.226	1260	0.307	0.405	0.025
IV6B5	0.2	0.32	0.05	1.310	1560	0.262	0.419	0.065
IV6B6	0.16	0.27	0.13	1.405	2160	0.225	0.379	0.183
IV6B7	0.27	0.27	0.06	1.538	2760	0.415	0.415	0.092
IV7A1	0.34	0.34	0.14	0.172	900	0.059	0.059	0.024
IV7A2	0.22	0.29	0.13	1.012	1050	0.223	0.293	0.132
IV7A3	0.17	0.28	0.09	1.300	1350	0.221	0.364	0.117
IV7A4	0.16	0.28	0.11	1.265	1650	0.202	0.354	0.139
IV7A5	0.13	0.27	0.09	1.271	1950	0.165	0.343	0.114
IV7A6	0.11	0.26	0.1	1.304	2550	0.143	0.339	0.130
IV7A7	0.09	0.26	0.09	1.390	3150	0.125	0.361	0.125
IV7B1	0.28	0.35	0.09	0.178	720	0.050	0.062	0.016
IV7B2	0.19	0.33	0.1	1.025	870	0.195	0.338	0.102
IV7B3	0.15	0.3	0.06	1.350	1170	0.202	0.405	0.081
IV7B4	0.13	0.3	0.06	1.449	1470	0.188	0.435	0.087
IV7B5	0.12	0.29	0.08	1.503	1770	0.180	0.436	0.120
IV7B6	0.1	0.3	0.06	1.555	2370	0.156	0.467	0.093
IV7B7	0.09	0.35	0.06	1.511	3030	0.136	0.529	0.091
IV8A1	0.55	0.36	0.1	0.013	570	0.007	0.005	0.001
IV8A2	0.37	0.36	0.2	0.047	720	0.017	0.017	0.009
IV8A3	0.18	0.33	0.12	0.994	1020	0.179	0.328	0.119
IV8A4	0.15	0.33	0.08	1.072	1320	0.161	0.354	0.086
IV8A5	0.13	0.33	0.08	1.311	1620	0.170	0.433	0.105
IV8A6	0.11	0.29	0.06	1.221	2220	0.134	0.354	0.073
IV8A7	0.1	0.29	0.09	1.441	2820	0.144	0.418	0.130
IV8B1	0.34	0.33	0.11	0.369	930	0.125	0.122	0.041
IV8B2	0.18	0.38	0.08	0.995	1080	0.179	0.378	0.080
IV8B3	0.14	0.35	0.11	1.168	1380	0.164	0.409	0.129
IV8B4	0.12	0.31	0.07	1.241	1680	0.149	0.385	0.087
IV8B5	0.11	0.31	0.06	1.348	1980	0.148	0.418	0.081
IV8B6	0.09	0.28	0.05	1.440	0.780	2580	0.130	0.403
IV8B7	0.09	0.3	0.08	1.399	0.787	3180	0.126	0.420

Sample Code	Ortho-P	NO3-N	NH4-N	Q	Time	O
		mg/L		L/s	s	
V1A1	3.12	2.35	1.5	0.023	540	0
V1A2	4.90	4.52	1.29	0.385	690	1
V1A3	3.35	2.32	1.04	0 947	990	3
V1A4	2.29	1.66	1.01	0.973	1290	2
V1A5	2.25	1.36	1.03	0.970	1590	2
V1A6	1.98	1.1	1.05	1.052	2190	2
V1A7	1.71	1.06	1.08	1.110	2790	1
V1B1	4.48	7.47	1.83	0.011	540	0
V1B2	6.33	8.84	1.33	0.344	690	2
V1B3	5.06	5.22	1.2	0.773	990	3
V1B4	4 46	3.75	1.15	0.872	1290	3
V1B5	4 04	3.1	1.12	0.887	1590	3
V1B6	3.27	2.29	1.09	0.904	2190	2
V1B7	3.07	1.67	1.11	0.904	2790	2
V2A1	6.42	9.9	1.89	0.027	540	0.
V2A2	7.03	16.12	1.97	0.265	690	1.
V2A3	5.84	12.26	1.84	0.940	960	5.
V2A4	6.51	9.66	1.72	1.107	1260	7.
V2A5	5.44	7.79	1.64	1.221	1560	6.
V2A6	4.82	4.4	1.47	1.171	2160	5.
V2A7	3.91	3.12	1.4	1.208	2760	4.
V2B1	8.28	21.38	2.47	0.033	870	0.
V2B2	5.02	10.42	1.87	0.495	1020	2.
V2B3	3.29	4.2	1.42	0.691	1320	2.
V2B4	2.81	3.2	1.36	0.745	1620	2.
V2B5	2.57	2.62	1.34	0.819	1920	2.
V2B6	1.28	1.88	1.27	0.853	2520	1.
V2B7	1.97	1.58	1 27	0.852	3120	1.
V3A1	15.43	38.47	4.68	0.033	810	0.
V3A2	11.49	27.39	4.11	0.571	960	6.
V3A3	7 46	15.91	3.51	0.772	1260	5.
V3A4	6.14	10.53	3.15	0.802	1560	4.
V3A5	5.25	8.17	2.91	0.966	1860	5.
V3A6	4.2	4 99	2.29	0.899	2460	3.
V3A7	3.56	3.58	2.1	1.017	3060	3.
V3B1	9.88	43.39	7.01	0.033	750	0.
V3B2	7.88	13.76	2.62	0.573	900	4.
V3B3	4.06	5.56	1.96	0 764	1200	3.
V3B4	3.27	4.08	1.81	0.796	1500	2.
V3B5	2.84	3.31	1.72	0.783	1800	2.
V3B6	2.32	2.23	1.62	0.917	2400	2.
V3B7	1.99	1.71	1.51	0.866	3000	1.
V4A1	1.22	1.29	1.65	0.012	750	0.0
V4A2	1.49	1.81	1.59	0.018	900	0.0
V4A3	1.41	1 85	1.29	0.048	1200	0.0
V4A4	1.16	1.21	1.18	0.197	1500	0.2
V4A5	1.12	1.27	1.19	0.317	1800	0.3
V4A6	0.96	1.11	1.17	0.528	2400	0.5
V4A7	0.91	1.04	1.19	0.695	3000	0 6
V4B1	2.52	5.67	1 94	0.019	810	0.0
V4B2	2.63	4.17	1.82	0.186	960	0 4
V4B3	2.07	3.39	1.7	0.364	1260	0.7
V4B4	1.8	2.95	1.6	0.498	1560	0.8
V4B5	1.57	2.34	1.61	0.619	1860	0.9
V4B6	1.28	1.62	1.51	0.871	2460	1.1
V4B7	1.18	1 38	1.52	1.050	3060	1.2

Sample Code	l Ortho-P	NO3-N	NH4-N	Q	Time	Ortho-P	NO3-N	NH4-N
		mg/L		L/s	s		Load mg/s	
V5A1	1.21	0.69	1.07	0.029	1350	0.035	0.020	0.031
V5A2	0.79	0.61	0.94	0.108	1500	0.085	0.066	0.101
V5A3	0.58	0.58	0.94	0.212	1800	0.123	0.123	0.199
V5A4	0.55	0.58	0.91	0.481	2100	0.265	0.279	0.438
V5A5	0.58	0.63	0.88	0.670	2400	0.389	0.422	0.590
V5A6	0.59	0.75	0.86	0.809	3000	0.478	0.607	0.696
V5B1	0.62	0.64	1.03	0.008	1290	0.005	0.005	0.008
V5B2	0.58	0.81	0.86	0.020	1440	0.011	0.016	0.017
V5B3	0 46	0.88	0.79	0.108	1740	0.050	0.095	0.086
V5B4	0 42	0.73	0.65	0.529	2040	0.222	0.386	0.344
V5B5	0.45	0.78	0.68	0.800	2340	0.360	0.624	0 544
V5B6	0.49	0.94	0.76	1.316	2940	0.645	1.237	1.000
V5B7	0.46	0.93	0.76	1.383	3540	0.636	1.286	1.051
V6A1	6.35	1	1.5	0.018	1230	0.117	0.018	0.028
V6A2	0.56	0.84	1.52	0.124	1380	0.070	0.104	0.189
V6A3	0.64	0.78	1.82	0.325	1680	0.208	0.253	0.591
V6A4	0.56	0.7	1.76	0.407	1980	0.228	0.285	0.716
V6A5	0.47	0.66	1.68	0.504	2280	0.237	0.332	0.846
V6A6	0.41	0.6	1.61	0.742	2880	0.304	0.445	1.195
V6A7		0.59	1.54	1.005	3480	0.000	0 593	1.547
V6B1	1.81	5.01	2.51	0.167	870	0.302	0 837	0 419
V6B2	1.15	1.79	2.22	0.370	1020	0.425	0.662	0 821
V6B3	0.89	1.19	2.08	0.614	1320	0.546	0.730	1.276
V6B4	0.72	0.8	1.73	0.742	1620	0.535	0.594	1.284
V6B5	0.69	1.08	1.34	0.902	1920	0.622	0.974	1.209
V6B6	0.5	0.67	1.49	1.139	2520	0.569	0.763	1.697
V6B7	0.43	0.64	1.4	1.291	3120	0.555	0.826	1.808
V7A1	0.81	0.84	1.29	0.072	43680	0.058	0.060	0.093
V7A2	0.6	0.87	1.17	1.179	43830	0.708	1.026	1 380
V7A3	0.41	0.71	1.2	1.318	44130	0.541	0.936	1.582
V7A4	0.35	0.63	1.1	1.374	44430	0.481	0.865	1.511
V7A5	0.31	0.62	1.09	1.446	44730	0.448	0.897	1.576
V7A6	0.28	0.56	1.12	1.378	45330	0.386	0.772	1 544
V7A7	0.26	0.56	1.14	1.408	45930	0.366	0.789	1.606
V7B1	0.28	0.43	0.8	0.145	43620	0.041	0.062	0.116
V7B2	0.25	0.43	0.74	0.967	43770	0.242	0.416	0.716
V7B3	0.23	0.49	0.81	1.398	44070	0.321	0 685	1.132
V7B4	0.2	0.49	0.89	1.400	44370	0 280	0.686	1 246
V7B5	0.2	0.51	0.92	1.405	44670	0.281	0.717	1.293
V7B6	0.19	0.5	1.02	1.418	45270	0.270	0.709	1.447
V7B7	0.18	0.51	1.07	1.425	45870	0.256	0.726	1.524
V8A1	0.81	1.08	1.79	0.018	630	0.014	0.019	0.032
V8A2	1.19	2.49	2.18	0.299	780	0.356	0.744	0.652
V8A3	0.49	0.72	1.5	0.810	1080	0 397	0.583	1.215
V8A4	0.39	0.62	1.23	0.925	1380	0.361	0.573	1 137
V8A5	0.34	0.61	1.26	1.012	1680	0.344	0 617	1.275
V8A6	0.29	0.59	1.23	1.269	2280	0.368	0.749	1 561
V8A7	0.26	0.69	1.27	1.388	2880	0.361	0.958	1.763
V8B1	0.54	0.6	1.29	0.631	630	0.340	0.378	0.813
V8B2	0.33	0.65	1.32	1.020	780	0.337	0.663	1.347
V8B3	0.27	0.59	1.31	1 040	1080	0.281	0.613	1.362
V8B4	0.24	0.51	1.34	1.017	1380	0.244	0.519	1.363
V8B5	0.23	0.52	1.29	1.033	1680	0.238	0.537	1.333
V8B6	0.21	0.52	1.32	1.289	2280	0.271	0.671	1.702
V8B7	0.2	0.55	1.3	1.333	2880	0.267	0.733	1.733

Sample Code	I Ortho-P	NO3-N	NH4-N	Q	Time	Ortho-P
		mg/L		L/s	s	
VI1A1	2.18	6.17	4.58	0.035	300	0.077
VI1A2	2.47	5.47	2.58	0.338	450	0.835
VI1A3	2.31	3.33	1.87	0.714	750	1.646
VI1A4	1.22	2.25	1.40	0.752	1050	0.915
VI1A5	1.15	1.51	1.26	0.822	1350	0.944
VI1A6	0.69	1.31	1.84	0.830	1950	0.571
VI1A7	0.69	0.68	0.69	0.931	2550	0.645
VI1B1	2.23	7.35	4.22	0.035	300	0.078
VI1B2	3.01	7.27	5.41	0.605	450	1.817
VI1B3	2.75	5.56	3.69	1.060	750	2.915
VI1B4	1.28	3.90	2.57	1.129	1050	1.443
VI1B5	1.54	2.69	2.39	1.107	1350	1.701
VI1B6	1.29	1.59	1.71	1.063	1950	1.371
VI1B7	1.10	1.15	1.34	1.058	2550	1.158
VI2A1	1.13	1.43	1.60	0.009	540	0.011
VI2A2	1.73	3.11	1.73	0.018	690	0.031
VI2A3	1.38	6.11	2.82	0.431	960	0.596
VI2A4	1.83	4.18	3.34	0.676	1260	1.239
VI2A5	0.92	3.17	2.30	0.820	1560	0.758
VI2A6	1.28	1.92	1.75	0.951	2160	1.214
VI2A7	0.71	1.38	1.32	1.008	2760	0.716
VI2B1	1.95	8.84	2.27	0.079	390	0.154
VI2B2	2.41	6.69	2.11	0.289	540	0.699
VI2B3	1.60	3.64	1.65	0.557	840	0.891
VI2B4	0.91	2.62	1.30	0.651	1140	0.592
VI2B5	0.75	1.98	1.06	0.711	1440	0.532
VI2B6	0.69	1.24	0.89	0.754	2040	0.521
VI2B7	0.52	0.88	0.78	0.844	2640	0.440
VI3A1	3.05	13.46	2.63	0.028	360	0.085
VI3A2	3.71	13.09	3.76	0.350	510	1.299
VI3A3	3.05	7.31	3.41	0.821	810	2.503
VI3A4	2.52	4.79	2.11	0.994	1110	2.505
VI3A5	1.72	3.60	1.89	1.017	1410	1.745
VI3A6	1.52	2.36	1.57	1.099	2010	1.666
VI3A7	1.41	1.78	1.22	1.173	2610	1.649
VI3B1	3.83	12.80	2.77	0.015	600	0.056
VI3B2	3.94	10.10	2.97	0.168	750	0.659
VI3B3	2.28	4.22	2.00	0.416	1050	0.949
VI3B4	1.61	2.77	1.41	0.565	1350	0.908
VI3B5	0.80	2.10	1.42	0.601	1650	0.480
VI3B6	1.07	1.30	1.19	0.604	2250	0.645
VI3B7	0.77	0.93	1.09	0.660	2850	0.508
VI4A1	2.18	5.12	3.32	0.021	660	0.045
VI4A2	2.26	5.82	2.28	0.097	810	0.219
VI4A3	1.81	4.68	1.19	0.337	1110	0.611
VI4A4	0.82	3.37	1.19	0.344	1410	0.281
VI4A5	1.07	2.35	1.01	0.432	1710	0.464
VI4A6	0.70	1.35	0.89	0.448	2310	0.315
VI4A7	0.52	0.84	0.92	0.454	2910	0.237
VI4B1	3.13	12.71	3.75	0.090	510	0.283
VI4B2	2.82	8.94	2.10	0.259	660	0.730
VI4B3	1.69	4.91	1.29	0.507	960	0.856
VI4B4	0.81	3.46	1.25	0.607	1260	0.492
VI4B5	0.88	2.51	1.25	0.593	1560	0.522
VI4B6	0.55	1.38	0.81	0.645	2160	0.355
VI4B7	0.38	0.87	0.73	0.662	2760	0.255

Sample Code	I Ortho-P	NO3-N	NH4-N	Q	Time	Ortho-P	NO3-N	NH4-N
		mg/L		L/s	s		Load mg/s	
VI5A1	0.08	0.04	0.27	0.008	5430	0.001	0.000	0.002
VI5A2	0.10	0.06	0.28	0.011	5580	0.001	0 001	0.003
VI5A3	0.08	0 00	0.25	0.037	5880	0.003	0.000	0.009
VI5A4	0.05	0 00	0.26	0.079	6180	0.004	0.000	0.021
VI5A5	0.10	0.11	0.28	0.097	6480	0.010	0.011	0.027
VI5A6	0.05	0.08	0.27	0.244	7080	0.013	0.020	0.065
VI5B1	0.10	0.10	0.27	0.249	7200	0.024	0.024	0.068
VI5B2	0.03	0.00	0.17	0.007	4320	0.000	0.000	0.001
VI5B3	0.04	0.11	0.25	0.008	4470	0.000	0.001	0.002
VI5B4	0.04	0.22	0.31	0.010	4770	0.000	0.002	0.003
VI5B5	0.05	0.24	0.32	0.036	5070	0.002	0.009	0.011
VI5B6	0.03	0.19	0.38	0.086	5370	0.003	0.017	0.032
VI5B7	0.05	0.27	0.42	0.297	5970	0.016	0.080	0.125
VI6A1	0.04	0.31	0.62	0.517	6570	0.018	0.160	0.320
VI6A2	1.18	2.40	1.35	0.087	750	0.102	0 208	0.118
VI6A3	0.80	1.83	1.18	0.164	900	0.131	0.300	0.194
VI6A4	0.27	0.93	0.98	0.215	1200	0.058	0.200	0.210
VI6A5	0.25	0.63	0.90	0.238	1500	0.059	0.150	0.213
VI6A6	0.19	0.45	0.81	0.253	1800	0.047	0.113	0.203
VI6A7	0.13	0.24	0.68	0.257	2400	0.033	0.062	0.175
VI6B1	0.09	0 11	0.56	0.223	3000	0.021	0.024	0.125
VI6B2	1.86	4.71	1.81	0.025	690	0.047	0.120	0.046
VI6B3	1.58	4.15	1.91	0.100	840	0.158	0.415	0.191
VI6B4	1.00	2.68	1.83	0.315	1140	0.315	0.844	0.577
VI6B5	0.52	1.69	1 53	0.428	1440	0.223	0.724	0.655
VI6B6	0.60	1.12	1.27	0.590	1740	0.356	0.663	0.746
VI6B7	0 17	0.68	1.30	0.420	2340	0.073	0.285	0.546
VI7A1	0.29	0.42	0.95	0.486	2940	0.141	0.204	0.460
VI7A2	0.23	0.31	0.48	0.008	2850	0.002	0.003	0.004
VI7A3	0.17	0.32	0 52	0.024	3000	0.004	0.008	0.012
VI7A4	0.19	0.25	0.48	0.045	3300	0.009	0.011	0 021
VI7A5	0 08	0.19	0.42	0.105	3600	0.008	0.020	0.044
VI7A6	0 07	0.17	0 45	0.137	3900	0.010	0 023	0 062
VI7A7	0.07	0.15	0.51	0.246	4500	0.017	0.038	0.126
VI7B1	0.11	0.12	0.37	0.488	5100	0.055	0.059	0.181
VI7B2	0.81	1.09	0.84	0.026	900	0.021	0.028	0.021
VI7B3	0.63	0.85	0.81	0.088	1050	0.055	0.074	0.071
VI7B4	0.25	0.51	0.67	0.195	1350	0.049	0.100	0.131
VI7B5	0.15	0.29	0.56	0.269	1650	0.040	0.077	0.150
VI7B6	0.10	0.17	0.46	0.267	1950	0.026	0.046	0.124
VI7B7	0.07	0.06	0.43	0.247	2550	0.018	0.014	0.107
VI8A1	0.10	0.02	0.37	0.265	3150	0.028	0.004	0.099
VI8A2	0.57	1.98	0.87	0.034	690	0.019	0 067	0.029
VI8A3	0.23	1.12	0.84	0.114	840	0.026	0 127	0.096
VI8A4	0.18	0.84	0.91	0.108	1140	0.019	0.090	0.098
VI8A5	0.26	0.50	0.67	0.138	1440	0.036	0.069	0.093
VI8A6	0 11	0.33	1.30	0.165	1740	0.017	0.055	0.216
VI8A7	0.07	0.13	0.48	0.206	2340	0.014	0.026	0.099
VI8B1	0.06	0.06	0.61	0.230	2940	0.015	0.014	0.141
VI8B2	0.29	0.95	0.78	0.057	780	0.017	0.054	0.044
VI8B3	0.26	0.72	0.80	0.063	930	0.016	0.045	0.050
VI8B4	0.34	0.47	0 64	0.080	1230	0.027	0.038	0 051
VI8B5	0.24	0.25	0.55	0.108	1530	0.026	0.027	0 059
VI8B6	0.20	0.15	0.49	0.109	1830	0.021	0.016	0.054
VI8B7	0.15	0.04	0.41	0.172	2430	0.025	0.007	0.071
VI8B7	0.09	0.00	0.36	0.205	3030	0.019	0.000	0.073

APPENDIX 5

SOIL ANALYSIS REPORT

Date	Location	Depth	Nitrate-N (ppm)	Ammoniacal-N (ppm)	Phosphorus (ppm)	OM (%)	pH	Soluble P (ppm)
4/29/1998	1A	0-2	13	36	89	3.9	5.3	8.25
4/29/1998	1A	2-6	4	23	35	2.4	5 1	1.7
4/29/1998	1B	0-2	9.5	29	175.5	4.0	5.3	17.3
4/29/1998	1B	2-6	6.5	23	56.5	5.0	5.1	3.2
4/29/1998	2A	0-2	16.5	36	173	2.9	5.4	10.15
4/29/1998	2A	2-6	8	23	46	4.3	5.4	1.45
4/29/1998	2B	0-2	9	31	133	2.9	5.1	86.5
4/29/1998	2B	2-6	6	24	43.5	4.3	5.2	1.75
4/29/1998	3A	0-2	5	31	56.5	3.1	4.9	4.35
4/29/1998	3A	2-6	4	22	31	4.1	5	1.85
4/29/1998	3B	0-2	14	29	64.5	2.6	5	5.25
4/29/1998	3B	2-6	11	20	33	3.8	5.1	1.75
4/29/1998	4A	0-2	2	29	55	2.8	5.1	3.05
4/29/1998	4A	2-6	1	25	13	4.3	5.1	1.15
4/29/1998	4B	0-2	8	34	62.5	2.6	5.1	3.7
4/29/1998	4B	2-6	5.5	25	25	4.3	5.2	1.05
4/29/1998	5A	0-2	3	25	52.5	3.9	5.3	5.15
4/29/1998	5A	2-6	6	31	40	4.5	5.3	2.35
4/29/1998	5B	0-2	3	34	57	3.2	5.4	4.35
4/29/1998	5B	2-6	6	24	29	4.0	5.4	1.55
4/29/1998	6A	0-2	3	28	34.5	2.7	5.1	2.1
4/29/1998	6A	2-6	2	22	16	3.8	5 1	0.85
4/29/1998	6B	0-2	2.5	35	31.5	2.1	5	1.75
4/29/1998	6B	2-6	1.5	24	14	2.8	5.0	0.7
4/29/1998	7A	0-2	2.5	28	40	4.4	5.2	2.55
4/29/1998	7A	2-6	1.5	26	15	2.6	5.5	0.9
4/29/1998	7B	0-2	2	37	33	4.0	5.1	2.5
4/29/1998	7B	2-6	2	25	14	2.7	5 1	0.8
4/29/1998	8A	0-2	0.5	33	31	4 1	4.9	2
4/29/1998	8A	2-6	0.5	25	16	3.0	5	0.75
4/29/1998	8B	0-2	3.5	25	28	4.2	5.2	2.2
4/29/1998	8B	2-6	2	23	14	2.5	5.3	0.85
5/22/1998	1A	0-2	94	12	138.5	4 1	5 2	11.4
5/22/1998	1A	2-6	50	6	29	2 7	4.9	1.15
5/22/1998	1B	0-2	92	14	151	4.4	5.4	12.5
5/22/1998	1B	2-6	53	6	52	2.7	5.2	2.5
5/22/1998	2A	0-2	54	15	95	3.7	5.3	5.6
5/22/1998	2A	2-6	27	7	31	2.3	5 3	1.25
5/22/1998	2B	0-2	79	10	92	3 8	4.7	5.1
5/22/1998	2B	2-6	28	6	14	2.3	5.2	0.5
5/22/1998	3A	0-2	86	13	77.5	4.1	4.6	6.7
5/22/1998	3A	2-6	57	7	20.5	2.9	4 7	1 15
5/22/1998	3B	0-2	89	13	80	4.5	4.6	7
5/22/1998	3B	2-6	47	7	16.5	3.9	4.8	0 85
5/22/1998	4A	0-2	56	10	39	2.3	5.0	1.45
5/22/1998	4A	2-6	42	7	12	4.2	4.6	0.55

5/22/1998	4B	0-2	102	14	98.5	2.6	4.9	2.85
5/22/1998	4B	2-6	60	9	20	4.4	5.4	0.65
5/22/1998	5A	0-2	19	11	34.5	3.8	5.3	2.45
5/22/1998	5A	2-6	23	12	15	4.7	5.4	0.07
5/22/1998	5B	0-2	14	21	40.5	4.1	5.4	3.1
5/22/1998	5B	2-6	14	10	22.5	4.1	5.2	1.55
5/22/1998	6A	0-2	14	17	40	2.8	5.5	1.05
5/22/1998	6A	2-6	7	13	21	3.7	5.1	0.45
5/22/1998	6B	0-2	16	17	39	2.5	5.4	0.75
5/22/1998	6B	2-6	6	13	20	3.4	5.4	0.04
5/22/1998	7A	0-2	13	12	36	2.8	5.8	1.15
5/22/1998	7A	2-6	5	11	21	3.8	5.1	0.04
5/22/1998	7B	0-2	14	14	29	2.7	5.5	0.85
5/22/1998	7B	2-6	5	14	20	3.8	5.1	0.35
5/22/1998	8A	0-2	11	18	29	3.0	5.5	0.9
5/22/1998	8A	2-6	3	15	18	4.1	5.4	0.35
5/22/1998	8B	0-2	12	13	27	2.1	6.7	0.75
5/22/1998	8B	2-6	8	11	16	2.7	5.7	0.5
10/26/1998	1A	0-2	48	24	157.5	3.5	5.8	15.55
10/26/1998	1A	2-6	19	7	34.5	2.4	5.3	1.4
10/26/1998	1B	0-2	56	26	156.5	4.0	5.5	14
10/26/1998	1B	2-6	24	8	45.5	2.4	5.3	1.9
10/26/1998	2A	0-2	60	19	125.5	3.6	5.3	9 45
10/26/1998	2A	2-6	32	6	27	2.0	5.4	0 85
10/26/1998	2B	0-2	49	21	139.5	3.2	5.3	9.5
10/26/1998	2B	2-6	28	4	32	2.2	5.2	1.25
10/26/1998	3A	0-2	42	23	57.5	3.3	4.8	3.45
10/26/1998	3A	2-6	27	7	20	2.9	5.0	0.85
10/26/1998	3B	0-2	45	27	117	3.7	5.0	10.4
10/26/1998	3B	2-6	25	5	31	2.5	5.4	1.1
10/26/1998	4A	0-2	34	13	35.5	3.1	5 0	1.35
10/26/1998	4A	2-6	27	2	13	2.4	5.2	0.6
10/26/1998	4B	0-2	36	7	54	3.8	5.0	2.4
10/26/1998	4B	2-6	30	5	14	2.2	5.1	0.4
10/26/1998	5A	0-2	19	8	43	3.9	5.9	1.9
10/26/1998	5A	2-6	21	3	16 5	3.5	5.8	0.65
10/26/1998	5B	0-2	29	15	56.5	5.1	5.5	5.6
10/26/1998	5B	2-6	22	11	49	4.9	5.4	5.4
10/26/1998	6A	0-2	16	9	23	4.1	5.3	1.45
10/26/1998	6A	2-6	11	4	19	2.9	5.5	0.5
10/26/1998	6B	0-2	22	20	21.5	4.0	5.3	1
10/26/1998	6B	2-6	7	10	14	2.7	5.4	0.75
10/26/1998	7A	0-2	17	15	31.5	4.3	5 7	1.55
10/26/1998	7A	2-6	7	6	22	2.6	5.9	0.5
10/26/1998	7B	0-2	9	20	33	4.0	5.3	1.4
10/26/1998	7B	2-6	7	6	11	2.6	5 5	0.6
10/26/1998	8A	0-2	9	13	21	4.1	5 3	1 15
10/26/1998	8A	2-6	3	13	15	4.7	5.6	1.15
10/26/1998	8B	0-2	2	10	15	3.1	5.5	1 05
10/26/1998	8B	2-6	3	4	10	2.9	5.6	0.7
5/13/1999	1A	0-2	6	23 2	131.5	4.9	5.3	12.11
5/13/1999	1A	2-6	3	13.5	38	2.1	5.3	1.71
5/13/1999	1B	0-2	10.5	24.9	134.5	4.9	5.3	12.87
5/13/1999	1B	2-6	3.5	14.4	35.5	2.2	5	2.19
5/13/1999	2A	0-2	16.5	31.7	80.5	5.5	5.3	5.3

5/13/1999	2A	2-6	7	16.4	23.5	2.2	5.2	0.87
5/13/1999	2B	0-2	4	30	93	5.8	5.1	6.3
5/13/1999	2B	2-6	2.5	15.4	35.5	2.1	5.1	1.41
5/13/1999	3A	0-2	5.5	30.9	55.5	6.5	4.7	5.22
5/13/1999	3A	2-6	2.5	18.3	23	3.4	4.8	1.73
5/13/1999	3B	0-2	3.5	27.4	55.5	6.1	4 8	4.9
5/13/1999	3B	2-6	3.5	23.1	31.5	3.2	4.8	2.01
5/13/1999	4A	0-2	2	30	45	4.9	4.8	2.12
5/13/1999	4A	2-6	2.5	21.1	22.5	2.7	5	1.18
5/13/1999	4B	0-2	4	29.9	63.5	5.4	4.9	3.94
5/13/1999	4B	2-6	2	23.3	30.5	2.9	4.9	1.69
5/13/1999	5A	0-2	2.5	28.6	71.5	6.0	5.6	5.08
5/13/1999	5A	2-6	2	22.7	32	4.0	5.4	2.29
5/13/1999	5B	0-2	4	28.2	50	7.0	5.1	5.32
5/13/1999	5B	2-6	1.5	21.5	31.5	4.5	5.2	2.55
5/13/1999	6A	0-2	1.5	33.8	30	5.6	5	1.76
5/13/1999	6A	2-6	1.5	23.1	15	3 1	5.1	0.91
5/13/1999	6B	0-2	1.5	34.1	26	5 5	4.9	1.75
5/13/1999	6B	2-6	1	24.2	16.5	3.2	4.9	0.78
5/13/1999	7A	0-2	1	29.5	23.5	6.2	5	2.08
5/13/1999	7A	2-6	1	21.3	14	3.6	5.3	1.18
5/13/1999	7B	0-2	1	33.5	26.5	5.7	4.9	1.45
5/13/1999	7B	2-6	0.5	22	13.5	2 9	4.7	0.87
5/13/1999	8A	0-2	1	29.5	25.5	5.4	4.9	1.7
5/13/1999	8A	2-6	0.5	19.9	13.5	3 0	4.9	0.86
5/13/1999	8B	0-2	1	26.7	20.5	5.1	5.1	1.73
5/13/1999	8B	2-6	0.5	18.1	14	3.0	5.2	0.97
6/25/1999	1A	0-2	19.5	23.7	144	5.27	5.2	8.34
6/25/1999	1A	2-6	13.5	16.3	53.5	2.98	5	3.38
6/25/1999	1B	0-2	20	23.1	155	5.23	5.2	9.91
6/25/1999	1B	2-6	14.5	14.5	47.5	2.44	5	1.96
6/25/1999	2A	0-2	31	28.2	121 5	5 19	5.2	5.54
6/25/1999	2A	2-6	27	18.8	38.5	2.61	5.2	1.83
6/25/1999	2B	0-2	29	29.6	124	5.96	5.1	6 6
6/25/1999	2B	2-6	16	21	51	2.79	4.8	1.8
6/25/1999	3A	0-2	51	28.5	72	5.73	4.5	3.84
6/25/1999	3A	2-6	49.5	18.5	35.5	3.3	4.7	1.73
6/25/1999	3B	0-2	27	22.7	67	4.45	4.6	3.66
6/25/1999	3B	2-6	22	14.6	28.5	2.5	4.9	1.36
6/25/1999	4A	0-2	20	29.2	46.5	4.67	4.7	1.93
6/25/1999	4A	2-6	14	20.7	26	3	4.8	1.47
6/25/1999	4B	0-2	28	27.3	57.5	4.37	4.7	2.53
6/25/1999	4B	2-6	22	18.8	26	2.61	4.9	1.45
6/25/1999	5A	0-2	3.5	30.4	57.5	5.29	5.4	3.45
6/25/1999	5A	2-6	4	19.9	25	3.84	5.2	1.03
6/25/1999	5B	0-2	2	27.7	46	6.52	5.2	2.38
6/25/1999	5B	2-6	9	23.9	43	5.24	5.1	2.38
6/25/1999	6A	0-2	1	39	35.5	5.84	5.3	1.72
6/25/1999	6A	2-6	2	22.5	20.5	2.76	4.9	0.8
6/25/1999	6B	0-2	7.5	35	35	5.23	5	1.55
6/25/1999	6B	2-6	1	26.9	17	3.4	5 1	0 99
6/25/1999	7A	0-2	1	33.5	32.5	6.23	5.2	2.01
6/25/1999	7A	2-6	2	20.7	15	3 7	5.3	0.95
6/25/1999	7B	0-2	3	33.9	23	4.94	4 9	1.13
6/25/1999	7B	2-6	1.5	22.3	12	3 1	4.9	0.72

6/25/1999	8A	0-2	1	32.2	36.5	6.1	5	1.69
6/25/1999	8A	2-6	4.5	22.4	48	3.74	5	1.52
6/25/1999	8B	0-2	0.5	28.4	21.5	5.07	5.3	1.35
6/25/1999	8B	2-6	1	18.8	12	3.0	5.2	0.95
10/7/1999	1A	0-2"	1.7	10.9	97	4.4	5.2	6.13
10/7/1999	1A	2-6"	8.8	7.1	21	1.6	5.1	1.49
10/7/1999	1B	0-2"	1.9	14.4	102	5.3	5.4	8.18
10/7/1999	1B	2-6"	5.1	8	27.5	1.8	5.2	1.46
10/7/1999	2A	0-2"	5.1	16.3	96.5	5.8	5.3	6.03
10/7/1999	2A	2-6"	13.1	10	29.5	2.2	5.2	1.03
10/7/1999	2B	0-2"	11.7	15.1	95.5	5.3	5.3	5.49
10/7/1999	2B	2-6"	6	10.9	29	1.9	5.1	1.23
10/7/1999	3A	0-2"	14	14.3	58.5	6.5	4.5	4.11
10/7/1999	3A	2-6"	15.8	9.7	26	2.4	4.7	1.14
10/7/1999	3B	0-2"	2.1	12.1	71.5	5.8	4.9	5.33
10/7/1999	3B	2-6"	13.8	8.5	28	2.4	5	1.28
10/7/1999	4A	0-2"	21.9	16.4	38.5	4.5	4.7	1.38
10/7/1999	4A	2-6"	3	10.5	14.5	2	5	0.67
10/7/1999	4B	0-2"	2.2	15	64	5	4.8	2.59
10/7/1999	4B	2-6"	19.7	10.5	18.5	1.4	4.7	0.74
10/7/1999	5A	0-2"	10.8	14.1	85.5	7	6	3.48
10/7/1999	5A	2-6"	6.9	12.3	33	3.9	5.4	1.59
10/7/1999	5B	0-2"	9.7	14.4	31	6.9	5.3	2.58
10/7/1999	5B	2-6"	3.2	11.5	9	3.2	5.4	0.74
10/7/1999	6A	0-2"	13.1	16.1	19.5	5.3	5	1.43
10/7/1999	6A	2-6"	6.7	11.6	9	2.6	5.1	0.64
10/7/1999	6B	0-2"	11	18.8	24.5	6.1	5	1.41
10/7/1999	6B	2-6"	7.1	15.7	11	2.6	5	0.64
10/7/1999	7A	0-2"	3.5	13.7	16	6.3	5.2	2.1
10/7/1999	7A	2-6"	3.5	13.7	10	3.4	5.4	1.09
10/7/1999	7B	0-2"	7.1	18.9	17	5.4	4.9	2.81
10/7/1999	7B	2-6"	3	15.1	9	2.6	5.1	2.14
10/7/1999	8A	0-2"	1.6	15.5	16	6.7	4.9	1.33
10/7/1999	8A	2-6"	2.7	13.5	8.5	2.9	5.1	1.56
10/7/1999	8B	0-2"	5.2	13.3	14	5.5	5.3	1.22
10/7/1999	8B	2-6"	10.6	12	21.5	4.6	5.3	2.46

APPENDIX 6

FLOW-WEIGHTED MEAN CONCENTRATION

Rainfall I	Flow, l		Flow-Weighted Mean Ortho-P, mg	NO3-N, mg	NH4-N, mg
1a	2100		2.29	0.31	3.05
1b	2040		3.35	0.34	2.98
2a	1420		1.07	0.34	1.39
2b	1050		1.59	0.27	1.04
		Average	2.07	0.32	2.12
3a	1390		0.51	0.24	0.79
3b	1250		0.39	0.20	0.82
4a	1180		0.83	0.36	1.05
4b	1470		0.45	0.34	1.11
		Average	0.54	0.28	0.94
	Average w/out plot 3		0.55	0.30	0.98
5a	1260		0.22	0.09	0.53
5b	327		0.26	0.07	0.51
6a	686		0.34	0.09	0.61
6b	1130		0.53	0.10	1.04
		Average	0.34	0.09	0.67
7a	1430		0.10	0.07	0.41
7b	1380		0.35	0.07	0.28
8a	606		0.09	0.07	0.61
8b	1130		0.10	0.08	0.38
		Average	0.16	0.07	0.42

Rainfall II			Flow-Weighted Mean		
Plot	Flow, l		Ortho-P, mg	NO3-N, mg	NH4-N, mg
1a	1560		8.00	6.16	4.96
1b	1480		7.82	4.79	4.45
2a	1010		2.33	1.03	2.74
2b	760		2.64	0.96	2.54
		Average	5.20	3.23	3.67
3a	1200		5.61	7.90	5.56
3b	1100		7.23	7.11	5.96
4a	342		1.75	5.65	4.62
4b	653		2.39	7.58	5.62
		Average	4.24	7.06	5.44
	Average w/out plot 3		2.07	6.61	5.12
5a	76.05		0.42	0.19	1.36
5b	211		0.25	0.06	0.45
6a	915		0.19	0.11	1.74
6b	443		0.83	0.28	2.64
		Average	0.42	0.16	1.55
7a	1374.07		0.10	0.10	1.36
7b	1331.22		0.27	0.12	1.36
8a	1098.71		0.14	0.06	1.50
8b	1490.18		0.19	0.10	1.24
		Average	0.18	0.10	1.37

Rainfall III			Flow-Weighted Mean		
	Flow, l		Ortho-P, mg	NO3-N, mg	NH4-N, mg
1a	1140		1.88	6.99	0.85
1b	1220		2.45	7.37	7.37
2a	1250		0.56	10.28	1.86
2b	1470		0.74	8.61	1.33
		Average	1.41	8.31	2.85
3a	887		1.39	7.49	1.04
3b	957		1.24	6.73	1.10
4a	1030		0.06	6.19	0.48
4b	1070		1.78	6.62	0.74
		Average	1.12	6.76	0.84
	Average w/out plot		0.92	6.41	0.61
5a	1520		0.26	5.86	0.62
5b	1710		0.07	6.26	0.50
6a	1060		0.10	5.92	0.20
6b	827		0.11	5.85	1.28
		Average	0.13	5.97	0.65
7a	2660		0.10	5.78	0.46
7b	3050		0.04	5.68	0.44
8a	1670		0.04	5.62	0.33
8b	2390		0.11	5.68	0.28

Rainfall IV

	Flow, l		Flow-Weighted Mean Ortho-P, mg	NO3-N, mg	NH4-N, mg
1a	2270		0.93	0.35	0.14
1b	2480		1.03	0.41	0.11
2a	2350		0.78	0.71	0.26
2b	2580		0.67	0.37	0.12
		Average	0.85	0.46	0.16
3a	2120		0.78	0.36	0.12
3b	2210		0.54	0.34	0.10
4a	2060		0.36	0.34	0.09
4b	1650		0.41	0.40	0.10
		Average	0.52	0.36	0.10
	Average w/out plot 3		0.38	0.37	0.09
5a	2080		0.29	0.28	0.10
5b	1910		0.34	0.31	0.10
6a	2130		0.20	0.29	0.07
6b	2670		0.23	0.31	0.08
		Average	0.26	0.30	0.09
7a	2780		0.14	0.27	0.10
7b	3240		0.12	0.31	0.07
8a	2390		0.13	0.31	0.08
8b	2860		0.11	0.31	0.07
		Average	0.12	0.30	0.08

Rainfall V			Flow-Weighted Mean		
	Flow, l		Ortho-P, mg	NO3-N, mg	NH4-N, mg
1a	2070		2.35	1.54	1.05
1b	1780		3.95	3.26	1.13
2a	2270		5.25	7.00	1.59
2b	1680		2.38	3.05	1.36
		Average	3.48	3.71	1.28
3a	1880		5.50	9.12	2.79
3b	1760		3.15	3.96	1.77
4a	746		1.00	1.15	1.19
4b	1420		1.47	2.06	1.57
		Average	2.78	4.07	1.83
	Average w/out plot 3		1.24	1.61	1.38
5a	1320		0.58	0.68	0.87
5b	1760		0.47	0.88	0.73
6a	1220		0.36	0.64	1.64
6b	1980		0.62	0.89	1.56
		Average	0.51	0.77	1.20
7a	2980		0.34	0.63	1.13
7b	2980		0.20	0.50	0.94
8a	2220		0.36	0.69	1.30
8b	2530		0.24	0.55	1.31
		Average	0.28	0.59	1.17

Rainfall VI			Flow-Weighted Mean		
	Flow, l		Ortho-P, mg	NO3-N, mg	NH4-N, mg
1a	1670		1.15	1.83	1.50
1b	2250		1.63	3.03	2.45
2a	1570		1.17	2.73	2.09
2b	1460		0.89	2.07	1.11
		Average	1.21	2.42	1.79
3a	2090		1.95	3.87	1.96
3b	1160		1.26	2.25	1.40
4a	827		0.95	2.28	1.04
4b	1250		0.89	2.68	1.09
		Average	1.26	2.77	1.37
	Average w/ plot 3		0.92	2.48	1.06
5a	184		0.07	0.07	0.27
5b	388		0.04	0.28	0.49
6a	514		0.23	0.55	0.80
6b	911		0.49	1.21	1.34
		Average	0.21	0.53	0.73
7a	406		0.09	0.15	0.45
7b	509		0.14	0.20	0.49
8a	370		0.12	0.34	0.76
8b	289		0.18	0.16	0.47
		Average	0.13	0.21	0.54

Vita 8

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